FISCAL YEAR 1992 DEPARTMENT OF ENERGY AUTHORIZATION

(Basic Energy Sciences)

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY

OF THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY HOUSE OF REPRESENTATIVES

ONE HUNDRED SECOND CONGRESS

FIRST SESSION

MARCH 19, 1991

[No. 15]

VOLUME V

Printed for the use of the
Committee on Science, Space, and Technology

U.S. GOVERNMENT PRINTING OFFICE

42-234 WASHINGTON : 1991

H701-44

For sale by the Superintendent of Documents, Congressional Sales Office
U.S. Government Printing Office, Washington, DC 20402

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1992 DEPARTMENT OF ENERGY AUTHORIZATION

TUESDAY, MARCH 19, 1991

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON ENERGY,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:30 a.m. in room 2318, Rayburn House Office Building, Hon. Tim Roemer presiding.

OPENING STATEMENT OF HON. TIM ROEMER, MEMBER, SUBCOMMITTEE ON ENERGY

Mr. ROEMER. The hearing on the Subcommittee on Energy will come to order. I ask unanimous consent that the subcommittee permit today's proceedings to be recorded by the public.

Today's hearing will review the budget request for the Basic Energy Sciences Program for fiscal year 1992. In addition, we will also examine funding for nuclear engineering education and university research reactors.

These are important programs in many respects. They contribute significantly to our Nation's competitiveness by providing knowledge applicable to new materials, chemicals and pharmaceuticals. These research disciplines also form the cornerstone for the technology developments that will reinforce our national energy strategy. These programs will provide the base of knowledge upon which the energy technologies for the next century will be built.

We have asked our witnesses to provide expert testimony in the area of materials science and to discuss the forthcoming National Initiative in materials science and engineering as it begins to take form and substance. We believe the Department of Energy and the national laboratories have an important role in helping to shape this initiative.

A directly related issue is the role of the user facilities operated by the national laboratories for the Nation's research community. These facilities are in the process of being modernized to provide world class scientific capabilities. Without such tools, a first class research capability in materials, chemistry and biology are not possible.

We await with interest the expert testimony of our panelists. We are anxious to learn of the progress we have been making and also to learn of the challenges and problems that these programs will face in the future.

I am very pleased to recognize our Distinguished Ranking Republican Member, the Honorable Sid Morrison, for his opening remarks.

I know you have been a highly valued member of this committee and have worked on the Basic Energy Sciences Program for many years. I look forward to your guidance, your expert advice and your continued interest in this program, Sid.

OPENING STATEMENT OF HON. SID MORRISON, MEMBER, SUBCOMMITTEE ON ENERGY

Mr. MORRISON. Thank you. I will just tell you how to vote when the time comes, and we will get along just fine.

Mr. ROEMER. I will sure listen to you, Sid.

Mr. MORRISON. No. Thank you, Mr. Chairman. I appreciate this. This is a learning opportunity for a number of us. As always, for some of our incoming members, sometimes the budget hearings seem a little perhaps more detailed than you want at this time, but it does all add together. Eventually, I think it helps this committee move us in a direction that we desperately need to go.

So I look forward to these programs today. Today, in fact, the basic research, the science research we are going to talk about today is so fundamental, that it is my hopes always that we can get a combination of our laboratories and universities with the cycle of the wheel turning so that scientific development leads to technological applications. That is what we are going to hear about today.

There are reasons to have some concerns because some of our key user facilities appear to be lagging behind competitive nations and an ever smaller competitive world. We have to look very carefully at user fees and the role that they are going to play, and always question whether they will be counterproductive or effective.

We are concerned about university research reactors and whether in fact, those should be receiving Department of Energy assistance for their replacement and upgrading.

I am delighted, Mr. Chairman, that one of my outstanding constituents is here, Mike Knotek, Senior Science Director with Pacific Northwest Laboratory in Richland, who will be testifying as part of the panel.

So thank you for the opportunity. I look forward to hearing from our witnesses.

Mr. ROEMER. You're welcome, Sid. Would any other members care to make an opening statement? Distinguished member from Alabama?

OPENING STATEMENT OF HON. BUD CRAMER, MEMBER, SUBCOMMITTEE ON ENERGY

Mr. CRAMER. Thank you, Mr. Chairman. It is a delight to serve with you here today. I, too, am a new member of this subcommittee and this full committee. I happen to be from Huntsville, Alabama. We have the Marshall Space Flight Program there. Our community is very interested in the Department of Energy's Basic Energy Science Program, and other programs that enhance science, mathematics, and engineering education, needless to say.

Our Nation faces a real challenge in science and technology and our basic efforts to maintain our world leadership in these vital areas. We are not producing enough highly qualified scientists and

engineers. This failure leads to deficiencies in qualified teachers being available to our young people, which results in a lag in our students on all levels in science, math and related disciplines.

I think a critical aspect of this problem is that minorities have not been drawn into these fields in sufficient numbers to meet our needs. A way must be found to address the issue of under-represented groups in science and engineering education. A place to start would seem to include support for our historically black colleges and universities. These institutions must be able to attract the best and brightest students and faculty, so that those schools may produce outstanding scientists and engineers. This would in turn encourage them to become teachers and would be an important step towards alleviating the problems that we are facing in the areas of science and engineering.

I look forward to Dr. Decker's comments. I have questions for you later on.

Thank you, Mr. Chairman, for conducting this hearing.

Mr. ROEMER. Thank you, Mr. Cramer. I appreciate your remarks. The distinguished member from Illinois, Mr. Fawell?

OPENING STATEMENT OF HON. HARRIS W. FAWELL, MEMBER, SUBCOMMITTEE ON ENERGY

Mr. FAWELL. Thank you, Mr. Chairman. I am pleased to have the opportunity to discuss the budget authorizations for several of the programs within the Department of Energy's Office of Energy research. These basic research programs play a vital role in maintaining our Nation's technological preeminence and our technological competitiveness.

I also would like to welcome to the subcommittee, Dr. Frank Fradin, who I believe lurks around here somewhere. As Associate Laboratory Director for Physical Research at Argonne National Lab, Dr. Fradin oversees Argonne's research and development programs and chemistry, material sciences, mathematics, high energy and nuclear physics and computer science. I look forward to the insight, which he will bring regarding the progress of research in these vital fields, particularly in materials science.

Also, I would like to welcome Dr. Dave Moncton, who is also here, hiding behind a beard. Is that right? That must be relatively new. Dave is, of course, the chief man in regard of the Advanced Photon Source. He has guided and is guiding the design and construction and operation of the APS, which will generate the Nation's most brilliant X-rays for materials research, condensed matter physics, biological medical research and chemistry.

We, in our area in Illinois, are just delighted with the progress that has taken place in that area. I am proud of the role that Argonne has taken place in general in the basic research area. I look forward to the testimony beginning with Dr. Decker.

Mr. ROEMER. Thank you, Mr. Fawell.

I share a committee with Mr. Fawell on Education and Labor. I am always astounded as to how he gets most of his constituency here. I have to learn from that.

The lead-off witness for our hearing today is Dr. James Decker, Acting Director of the Office of Energy Research from the Department of Energy.

Dr. Decker, welcome. We are pleased to have you with us today. We look forward to your testimony. Would you please proceed?

STATEMENT OF DR. JAMES F. DECKER, ACTING DIRECTOR, OFFICE OF ENERGY RESEARCH, DEPARTMENT OF ENERGY; ACCOMPANIED BY DR. LOUIS C. IANNIELLO, U.S. DEPARTMENT OF ENERGY

Dr. DECKER. Thank you, Mr. Chairman, Members of the Committee. I am pleased to be here today to discuss the fiscal year 1992 budget requests for several programs supported by the Office of Energy Research. These programs are Basic Energy Sciences, Energy Research Analyses, University and Science Education, Multiprogram Energy Laboratories-Facilities Support.

The total request for these programs is about $800 million, of which $715 million is for the Basic Energy Sciences Program. Most of my remarks will focus on that program.

On February 20th, the President announced the National Energy Strategy, which includes an explicit goal of maintaining U.S. preeminence in fundamental science and engineering through a commitment to fundamental research. This commitment to longer term research recognized that scientific discoveries and their exploitation continue to be the principal source for innovation and economic growth. The missions of the programs I am addressing today directly support all of the National Energy Strategy goals aimed at ensuring U.S. energy security economic growth and environmental progress in the future.

History has shown that the outcome of basic research is difficult to predict. Societal benefits are not always recognized until many years later. Basic scientific research leads to new technologies, the result of new products and processes that benefit all of us. This is why, even in this difficult deficit reduction situation we face, I believe the Federal Government should continue to strongly support basic research as an important investment in the Nation's future.

For example, basic research in mathematics and computer science has led to high performance computers, which are now being used to simulate complex phenomena very critical to understanding energy processes, such as combustion in automobile engines, global weather patterns, and the movement of pollutants below the Earth's surface.

Materials research is another example that contributes to the development of advanced materials that can improve performance and efficiency in energy systems. Materials research leads to the capability to tailor the properties of materials to satisfy specific needs, such as improved corrosion resistance in fossil plants.

Each of the Basic Energy Sciences subprograms—materials, chemicals sciences, applied mathematical sciences, engineering and geosciences, advanced energy projects and energy biosciences supports research projects whose results ultimately have applications to a broad range of technologies.

The broad impact of the Basic Energy Sciences Program is also seen in the nature and number of institutions and individuals it supports. The program supports 1,300 individual research projects at over 200 separate institutions each year. These include direct support of about 4,000 investigators and 2,300 graduate students in the physical biological and mathematical sciences. Many of these investigators are faculty at universities throughout the country.

Support for major user facilities at the DOE laboratories, such as Synchrotron Radiation and Neutron Sources, account for a significant portion of the Basic Energy Sciences budget. These national facilities are unique tools essential for many of today's forefront research needs.

Approximately 2,800 users were accommodated at the seven major Basic Energy Sciences user facilities in fiscal year 1990. These facilities are the National Synchrotron Light Source and the High Flux Beam Reactor at Brookhaven National Laboratory; the Stanford Synchrotron Radiation Laboratory; the Combustion Research Facility at Sandia-Livermore; the High Flux Isotope Reactor at Oak Ridge National Laboratory; the Intense Pulsed Neutron Source at Argonne National Laboratory; and the Manuel Lujan, Jr. Neutron Scattering Center at Los Alamos National Laboratory.

A wide variety of research is being carried out in these facilities by the private sector. At the Synchrotron Light Source, for example, the largest U.S. companies are doing research in such areas as catalysis, biomedical applications and electronics.

At the Neutron Source, major oil companies are investigating the porosity of geologic formations.

Advances in materials, chemistry, biology and the next generation of computer chips truly depend on these user facilities.

To meet the ever-increasing demand for additional research time and for newer advanced capabilities, we are requesting construction funding of $108 million in fiscal year 1992. This will provide funds to complete the construction of the Advanced Light Source a 1–2 GeV Synchrotron Radiation Facility at the Lawrence Berkeley Laboratory. The Advanced Light Source will provide new capabilities for studies of surfaces and gasses.

Funds are also requested to continue the construction of the Advanced Photon Source, a 6–7 GeV synchrotron radiation facility at Argonne National Laboratory, which will provide more penetrating higher intensity beams to study solids and fluids.

Research and development support will continue in fiscal year 1992 to complete the conceptual design for the Advanced Neutron Source. The Advanced Neutron Source, if constructed, would be a world class research reactor at the Oak Ridge National Laboratory. It would greatly increase our capability to study the structure of materials, produce radioactive and heavy element isotopes and conduct research on radiation effects on materials.

The Advanced Neutron Source, with much greater state of the art capability, would replace two Department research reactors, which have been in service since the mid-1960s.

I would like to take a few minutes to describe the Department's role in the President's High Performance Computing and Communications Initiative. For over 40 years, the Department has been a pioneer in the use of supercomputers for modeling complex physi-

cal systems. Today, we are one of the largest users of high performance computers.

Because of the importance of high performance computers to our mission, the Department is playing a major role in the President's Initiative. The major goal of this Initiative is to maintain and extend U.S. leadership in high performance computing.

The increased funding for this activity in fiscal year 1992 would provide for cooperation with other agencies and development and evaluation of new computer systems to be used for computations important to a wide variety of Department activities. The new computer systems are expected to provide a thousand-fold increase in computing by 1996. This will make possible major advances in critical computational applications, such as modeling global climate change, superconducting materials, catalysis and fusion research.

We will also be cooperating with the other agencies to develop and deploy the National Research and Education Network. Access to the Department's widely distributed supercomputers and large experiments depends on high speed, reliable data networks. We need the hundred-fold improvement in network speed that the program will develop.

I would like to conclude by briefly discussing our science, mathematics and engineering education programs. Improving education and science and mathematics is one of the cornerstones of the National Energy Strategy. The Office of Energy Research plays a strong role in this area.

The existing crisis in science education has some serious implications for the Nation's future economic and technological positions. For instance, the number of young Americans, including women and minorities, interested in pursuing careers in science and engineering is declining. Also, too often, the preparation received by young students who are interested in such careers is inadequate.

Since October of 1989, DOE's sponsored conference in education held in California, the Department has developed a number of major science and mathematics education initiatives. These are centered around our national laboratories and research facilities and carried out in collaboration with public and private sector partners.

There are eight major new partnerships that were established in fiscal year 1990 and fiscal year 1991 linking our laboratories with regional, urban and rural districts. Perhaps the most ambitious of the partnerships involved support provided by the Department to help establish the Academy for Mathematics and Science Teachers in Chicago. Linking together all the major university and industrial and Federal laboratories in the Chicago region, this Academy's purpose is to retrain some 17,000 mathematics and science teachers in the Chicago public school system within the next six to eight years.

Other initiatives also are underway with local school systems in Tennessee, Texas, New Mexico, Idaho and Washington.

Mr. Chairman, that concludes my oral remarks. I would be happy to answer any questions you may have.

[The prepared statement of Dr. Decker follows:]

Statement of James F. Decker

Acting Director

Office of Energy Research

Department of Energy

before the

Subcommittee on Energy

of the

Science, Space, and Technology Committee

U. S. House of Representatives

March 19, 1991

Madam Chairman and members of the Subcommittee:

It is a pleasure to be here today to discuss the FY 1992 budget request for several of the programs supported by the Office of Energy Research (ER). These programs are: Basic Energy Sciences, Energy Research Analyses, University and Science Education, Multiprogram Energy Laboratories-Facilities Support, and supporting program direction. The missions of these programs directly support the National Energy Strategy goals aimed at strengthening the foundations of future U.S. energy security, economic growth, and environmental progress. Table 1 shows the total ER FY 1992 request of about $3 billion, including the programs that I will discuss today. The first of these is Basic Energy Sciences (BES).

BASIC ENERGY SCIENCES

Results from research sponsored by the BES program provide the foundation for new technologies and improvements to existing technologies that can have a major impact not only on the Nation's economy, but also on our daily lives. Research supported by BES is primarily driven by the need for enhanced knowledge or understanding which currently limits existing technologies.

The link between basic research and applications, however, is not generally confined to any single energy or technology problem. For example, basic research in mathematics and computer science has led to high performance parallel processing computers which are now being used to simulate phenomena that are critical to energy processes but difficult to observe, such as combustion in automobile engines, global weather patterns, and the movement of pollutants below the earth's surface. Each of the BES subprograms--Materials

Table 1
Office of Energy Research
Summary by Program
Budget Authority
($ in millions)

	FY 1990	FY 1991	FY 1992 Request
Energy Supply R&D			
Basic Energy Sciences	$ 564.1	$ 711.8	$ 714.7
Fusion Energy	316.7	289.6[a/]	337.1
Biological & Environmental Research	305.4	393.9	312.6
University and Science Education	29.5	46.6	48.9
Energy Research Analyses	3.8	3.6	4.0
Multiprogram Energy Laboratories-Facilities Support	22.1	23.6	23.9
Advisory & Oversight Program Direction	3.3	4.2	10.1
Policy and Management	.7	.8	1.2
Small Business Innovation Research	39.3	0	0
Subtotal	$1,284.9	$1,474.1	$1,452.5
General Science & Research			
High Energy Physics	$ 576.3	$ 588.6	$ 666.4
Superconducting Super Collider	216.9	242.9	533.7
Nuclear Physics	287.2	313.3	342.4
General Science Program Direction	3.8	3.9	6.4
Subtotal	$1,084.2	$1,148.7	$1,548.9
Total ER	$2,369.1	$2,622.8	$3,001.4

[a/] Includes approved reprogramming request of $16.0 million.

Sciences, Chemical Sciences, Applied Mathematical Sciences, Engineering and Geosciences, Advanced Energy Projects and Energy Biosciences--supports research projects whose results ultimately have applications across a broad range of technologies. Whether the issue is how to burn fuel more efficiently or how to reduce the overall volume or hazards from waste materials, the solution will rely to a large extent on advances in basic research and the application of those advances to the appropriate technology.

While the principal focus of the BES program is directed toward supporting the Department's energy R&D goals, a number of other important national goals are also supported, including U.S. leadership in science and technology, the stimulation of economic growth and national defense, and the training of tomorrow's scientists.

The broad impact of the BES program is also seen in the nature and number of institutions and individuals it supports. The program supports about 1300 individual research projects at over 200 separate institutions each year. That includes direct support for about 4000 investigators in the physical, biological and mathematical sciences and over 2000 graduate students. Many of those investigators are faculty or students carrying out research at universities.

Support for major, complex user facilities at the DOE laboratories, such as synchrotron radiation sources and neutron sources, accounts for a significant amount of the BES budget. These national facilities are maintained and operated for the benefit of all qualified researchers from Government

laboratories, academia, and industrial laboratories. Approximately 2800 users were accommodated at the seven major BES scientific user facilities in FY 1990. These facilities include: the National Synchrotron Light Source at Brookhaven National Laboratory (BNL); the Stanford Synchrotron Radiation Laboratory; the Combustion Research Facility at Sandia-Livermore; the High Flux Isotope Reactor at Oak Ridge National Laboratory (ORNL); the High Flux Beam Reactor at BNL; the Intense Pulsed Neutron Source at Argonne National Laboratory (ANL); and the Manuel Lujan, Jr. Neutron Scattering Center at Los Alamos National Laboratory (LANL).

To fully appreciate the importance of the seven major BES user facilities, one needs only look at the variety of research being carried out in these facilities by the private sector. At the synchrotron light sources, for instance, the largest U.S. companies are doing research in such areas as catalysis, polymers, biomedical applications and electronics; and major oil companies are investigating the porosity of geologic formations using the neutron sources. Advances in materials, chemistry, biology, and the next generation of computer chips truly depend on these facilities.

Approximately 70 percent of the BES-supported research is carried out at the national laboratories, where all but one of the major BES user facilities are located. Since these laboratories are also involved in many aspects of the applied energy programs, they are skilled at facilitating the transfer of scientific information and technology from fundamental research to application. The BES program also provides significant direct funding support

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to universities, in addition to providing them with research time at the various user facilities.

Although it is impossible to predict the results of basic research, the following examples of recent accomplishments reflect the diversity and significance of the research supported with the funds appropriated by Congress:

- Research Yields R&D 100 Award and Start of New Company. The thermite reduction process, which was developed at Ames Laboratory, has received a 1990 R&D 100 Award and has led to a commercial application and establishment of a new company. A license has been granted to produce rare earth iron alloys using this process, which is faster, simpler and less expensive than traditional methods. These alloys are used to make smaller and stronger permanent magnets that could lead to smaller motors and lighter, more compact products, including more fuel efficient automobiles.

- Newly Developed Electron Microscope Improves Our Ability to Better Understand Superconductors. The new "Z-Contrast" transmission electron microscope, developed at ORNL, is also an R&D-100 Award winner. The new electron microscopy technique is capable of imaging an individual atom using a focused electron beam rather than a conventional parallel beam. This new capability provides a 35 percent improvement in resolution compared to a conventional microscope and will allow researchers to determine both structure and chemical composition at the atomic level.

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For example, this improved resolution will allow scientists to determine the composition of elements affecting the properties of superconductors. This new information can then be used to improve existing superconductors, which are used in a variety of technologies, as well as to develop new ones.

- New Class of "Thin Film" Materials Holds Promise for Improved Batteries and Energy Efficient Windows. A new class of silicon-based, ion-conducting polymers with the highest room temperature conductivity ever measured for such materials has been developed at BNL. Room temperature conductivity was 10 times higher than for any other polymeric material. This development is expected to have an important impact on thin film electrochemical energy technologies, particularly rechargeable lithium batteries and more energy efficient windows which react to sunlight and increase or decrease transmitted light automatically.

- Molecular Device Used to Create Artificial Photosynthesis. The capture of light and its efficient conversion to chemical energy has been achieved with a five-part molecule designed and synthesized by researchers at Arizona State University. The researchers used a strategy similar to that of natural organisms that are able to convert light energy to chemical energy. In the Arizona State experiment, when visible light was absorbed by one part of the molecule, an electrical charge was produced that was separated by a multi-step electron transfer process. This molecular device for artificial photosynthesis is the most successful prepared to date. It will help us to understand the

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photosynthesis process, the mechanism by which sunlight is converted to chemical energy in plants.

- Discovery of Gene Transfer System Makes it Possible to Study Bacteria with Potential for Combating Environmental Problems. Researchers at the University of Missouri have discovered a virus with the ability to transfer genes between various strains of sulfate-reducing bacteria. These bacteria convert sulfates into hydrogen sulfide instead of converting oxygen to water as normally occurs in larger organisms. These sulfate-reducing bacteria play critical roles in the global sulphur cycle, acidifying of oil, sewage treatment, metal corrosion and other fermentation processes that take place in oxygen-depleted environments. The development of the viral transfer system has made possible extensive genetic studies on these bacteria. With additional insights, it may be possible to use this virus to handle some of the damaging environmental problems facing the Nation.

- New Computer Design and Software Improves U.S. Capability for Advanced Computers and Communications. Using a recently introduced, high performance parallel processor system, solid state physicists and computer scientists at ORNL have teamed up to study one of today's most important materials problems through computational experiments. The study succeeded in improving our understanding of the possible mechanisms involved in high temperature superconductivity by calculating the electronic structure of selected superconductors. The study also verified a significant improvement in our computing capabilities in that

the computer codes used in this research, which were developed using new U.S. software technology, ran in less time on the new parallel processor than on existing modern, large-scale computers. Furthermore, the cost of the new parallel processor system is less than 30 percent of the modern, large-scale computer systems. This accomplishment is strong evidence of the capabilities and cost-effectiveness of the new U.S. parallel processor systems and American software. This achievement provides the foundation for future computational advances in the 1990s. This and other similar advances support the High Performance Computing and Communications Program slated to begin in FY 1992 and discussed in more detail later in this statement.

FY 1992 BASIC ENERGY SCIENCES BUDGET REQUEST

The FY 1992 budget request for Basic Energy Sciences is $714.7 million. The request includes $569.7 million for Operating Expenses, $37.0 million for Capital Equipment, and $108.0 million for Construction. (Table 2)

The Operating Expenses request continues a strong core research program and provides cost of living increases for each of the BES subprograms. Research in Materials Sciences, with a request of $257.1 million, continues to improve our theoretical and experimental capability to analyze the fundamental structure and behavior of materials. In doing so, materials research contributes to the development of advanced materials that can improve performance and efficiency in energy systems. It creates the capability to tailor materials properties to satisfy defined requirements, such as improved

Table 2
Energy Supply R&D
Basic Energy Sciences
Budget Authority
($ in millions)

	FY 1990	FY 1991	FY 1992 Request
Operating Expenses			
Materials Sciences	$ 196.2	$ 274.9	$ 257.1
Chemical Sciences	138.4	157.6	158.3
Applied Mathematical Sciences	43.2	52.7	75.5
Engineering and Geosciences	32.8	34.3	35.8
Advanced Energy Projects	14.4	24.9	10.8
Energy Biosciences	20.4	22.1	24.7
Program Direction	5.4	6.1	7.5
Subtotal	$ 450.8	$ 572.6	$ 569.7
Capital Equipment	36.5	36.8	37.0
Construction	76.8	102.4	108.0
Total Basic Energy Sciences	$ 564.1	$ 711.8	$ 714.7

corrosion resistance in fossil plants, and the ability to predict materials problems and service life. The FY 1992 request of $257.1 million will provide for continuing research programs in areas such as high temperature superconductivity, solid state physics, materials chemistry, metallurgy, and ceramics. R&D support for the Advanced Neutron Source (ANS) will continue with additional funds provided for completion of a conceptual design for the facility. The ANS will be a forefront research reactor at ORNL which will greatly increase our capability to study the structure of materials, produce radioactive and heavy element isotopes, and conduct research on radiation effects on materials. Isotopes produced in the reactor will have important industrial and medical applications, such as for cancer therapy. The request also provides increases for operations and R&D on the 1-2 GeV and 6-7 GeV Synchrotron Radiation Sources, which are discussed later in this statement. Funding for support of major scientific user facilities, which were discussed earlier in my statement, is also included as part of the Materials Sciences request.

The Chemical Sciences subprogram, with an FY 1992 request of $158.3 million, investigates the chemical properties of matter and the interactions of the component molecules, atoms, ions, and electrons. Chemical sciences research ultimately affects such areas as production of fuels and chemicals from coal, nuclear waste separation, conversion of biomass (such as wood and leafy materials) into liquid fuels, and detection and measurement of harmful products of energy processes. In FY 1992, the research program will emphasize areas relevant to improved chemical separations, the environment, waste

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management, and combustion. The FY 1992 budget request also includes support for major scientific user facilities.

Applied Mathematical Sciences supports long-range mathematical and computational research. This subprogram advances all aspects of scientific computation--from proofs of theorems to understanding the structure of parallel computer systems. The FY 1992 request of $75.5 million reflects an increase of $22.8 million. The requested funds will provide for the core research program and will allow the program to continue to provide access to, and expand the capabilities of the Department's state-of-the-art supercomputing facilities that are essential for researchers supported by ER.

A major portion of the requested increase will provide for DOE's support of the President's High Performance Computing and Communications (HPCC) initiative. The HPCC initiative, with total ER-requested funding of $93 million in FY 1992, is supported in the Applied Mathematical Sciences subprogram and in the Biological and Environmental Research and Fusion Energy programs. This initiative recognizes the need to maintain and extend U.S. leadership in high performance computing and is critical to U.S. competitiveness in the 1990's and into the 21st century. As a major user of high performance computers and a pioneer in the use of supercomputers for modeling complex physical systems that are too expensive or poorly understood to build and test, DOE is playing a major role in the President's effort to improve high performance computing. The increased funding for this activity in FY 1992 provides for research, assessment, and development of new computer architectures to be used in computations and modeling important to energy

systems. For example, the new architectures will be applied to such "grand challenges" as modeling global climate changes accurately over the next few centuries under differing energy scenarios. A wide range of issues will be taken into consideration in developing these new architectures, including privacy, performance, security, and distributed processing to improve communications between high performance computers, ER's Energy Sciences Network, and the National Research and Education Network. The ultimate goal is to be able to perform trillions of arithmetic operations per second over networks carrying a billion bits per second. Another, equally important, goal of the HPCC initiative is to encourage young men and women to pursue careers in science and engineering and to participate in the computational sciences in the U.S. The Applied Mathematical Sciences subprogram will contribute to achieving that goal by providing scholarships, fellowships, and opportunities for post-graduate students to participate in R&D sponsored by the subprogram.

The Engineering and Geosciences subprogram, with an FY 1992 request of $35.8 million, includes two broad disciplines. Research in engineering aims to expand our knowledge of the processes and concepts that underlie current engineering practice in energy technologies and to broaden the technical and conceptual base for solving future problems. The FY 1992 request provides for modest growth in fundamental engineering research with emphasis on topics important for energy production and use, as well as those meeting the Department's long-term objectives for restoration of the environment. Such topics include flow of oil, gas, and water through porous materials such as soil and rocks and two phase flow in energy systems--for instance, mixtures of water and steam in nuclear reactors. Work is also underway on what are called

intelligent machines, for example, the mobile robots to be used for cleanup of contaminated sites. Geosciences research emphasizes the development of a predictive understanding of the energy-related aspects of geological, geophysical, and geochemical processes related to the Earth. The FY 1992 request provides for modest growth and will emphasize high-resolution underground imaging related to enhanced oil recovery and waste management, as well as continental scientific drilling. In the latter area, site studies to investigate existing geological structures will be carried out at Katmai, Alaska. The Environmental Impact Statement for this project will be completed in FY 1992 before any site drilling takes place.

The Advanced Energy Projects subprogram, with an FY 1992 request of $10.8 million, explores the feasibility of novel, energy-related concepts evolving from basic research that are at an early stage of scientific definition and, therefore, are not yet of practical use to technology programs. The FY 1992 request will continue existing projects including an innovative technique for cleaning oil spills, an unconventional approach to fossil fuel technology, and a novel processing technique for high-temperature superconducting materials. As projects are completed, available funds will be used to initiate approximately 10 promising new projects. Also in the FY 1992 budget, the Heavy Ion Fusion Accelerator Research effort, previously supported under the Advanced Energy Projects subprogram, will be transferred to ER's Office of Fusion Energy in keeping with the Department's decision to pursue the development of both magnetic and inertial confinement fusion energy.

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The FY 1992 request for the Energy Biosciences subprogram is $24.7 million. Research in this area continues to increase our understanding of basic biological principles, biological mechanisms, and organisms useful for energy applications, such as the production of fuels from biomass materials. The FY 1992 request provides for continued growth in this subprogram's core program in plant and microbial sciences, including support for the plant science centers supported jointly by the Department, the National Science Foundation, and the Department of Agriculture.

The Program Direction request for FY 1992 is $7.5 million. This request provides funds for the salaries, benefits, travel and other expenses related to 71 full-time equivalent employees required to administer the BES program.

The BES Capital Equipment request for FY 1992 is $37.0 million. These funds will ensure that BES-supported researchers will continue to have the equipment needed to initiate and continue advanced research, much of which involves experiments at extremes of temperature and pressure. Reliable, precise measurements under these conditions challenge the current state-of-the-art. Replacement and new equipment funded under this request, which are important to the continued success of the program, include such items as electron microscopes, neutron spectrometers, molecular beam equipment and computers for equipment control and data analysis.

The FY 1992 Construction request of $108.0 million (Table 3) includes funding for the final year of construction for the 1-2 GeV Synchrotron Radiation

Table 3
Energy Supply R&D
Basic Energy Sciences
Construction Summary
($ in millions)

Project	TEC	FY 1991	FY 1992 Request
1-2 GeV Synchrotron Radiation Source (LBL) (87-R-406)	$ 99.5	$ 22.9	$ 6.5
6-7 GeV Synchrotron Radiation Source (ANL) (89-R-402)	456.0	69.6	90.4
Accelerator and Reactor Improvements Projects	N/A	6.9	6.6
General Plant Projects (GPE-400)	N/A	3.0	4.5
Total Construction	N/A	$ 102.4	$ 108.0

Source at LBL as well as continuation of construction of the 6-7 GeV Synchrotron Radiation Source at ANL. Both facilities are needed to cover the entire radiation range needed for experiments supported by the BES program. The 1-2 GeV project is an advanced light source which will provide radiation in the vacuum ultra violet/soft x-ray range to permit studies of surfaces and gases. The unique capabilities of this facility will make possible new basic and applied science studies in such areas as materials and surface science, atomic and molecular physics, chemistry, and biology. The 6-7 GeV project is a new, hard x-ray synchrotron light source which has been rated as the top priority by several scientific panels, including one from the National Academy of Sciences. It will provide brilliant x-ray beams that will serve the research needs of virtually all scientific disciplines and many technology fields by offering radiation which can penetrate into a substance to determine its structure. The FY 1992 request includes $6.5 million in construction funds for the 1-2 GeV project and $90.4 million for the 6-7 GeV project, as well as increased support for R&D and commissioning of selected components for both projects. Of the remaining $11.1 million, $6.6 million is for Accelerator and Reactor Improvements Projects and $4.5 million is for General Plant Projects. Each of these categories is comprised of smaller projects which are necessary to maintain plant and facilities at several DOE laboratories. The projects include a wide spectrum of improvements necessary to protect property and personnel and to modify existing scientific facilities to allow the most cost-effective utilization of their technical capabilities.

ENERGY RESEARCH ANALYSES

The Energy Research Analyses program carries out technical assessments on the Department's civilian R&D programs. The assessments include comprehensive project-by-project evaluations as well as assessments of the directions that future R&D should take to be more productive and relevant to DOE missions. In 1990, reviews of several DOE programs were completed, including radon, photovoltaics, radiation biology and the Fossil Energy Advanced Research Program. Program managers took significant actions as a result of these reviews, including project terminations or reformulations. The program also provides funds under the National Acid Precipitation Assessment Program (NAPAP) for summarizing the state of the science in acid rain research and for producing assessment reports needed by policymakers.

The FY 1992 budget request of $4.0 million will provide funding for technical assessments of programs in the Office of Energy Research, as well as programs under the Assistant Secretary for Fossil Energy and the Assistant Secretary for Conservation and Renewable Energy. In addition, funds will be provided for the continuation of NAPAP as called for by the Clean Air Act Amendments of 1990.

UNIVERSITY AND SCIENCE EDUCATION

The existing crisis in science education has serious implications for the Nation's continued international economic and technological competitiveness. The crisis is particularly evident in the declining number of young Americans,

including women and minorities, interested in pursuing careers in science and engineering. The problem is further compounded by the often inadequate preparation received by young students who are interested in such careers. The Administration has designated the improvement of science and mathematics education as one of the six goals for education reform by the turn of the century. This includes the goal of making U.S. students first in the world in knowledge of mathematics and science by the year 2000.

The crisis in science education also has serious implications for the Department's ability to carry out its science, energy, and defense R&D missions. As both a user and a patron of a large fraction of the Nation's scientists and engineers, DOE is uniquely positioned to provide major assistance to the national effort to strengthen science and engineering education. The Department's long tradition of support for science education continues today. Seven of our laboratories have been designated as Science Education Centers capable of carrying out comprehensive science education programs at the precollege and university level. Our efforts are in direct support of the priorities for science education established by the Federal Coordinating Council on Science, Engineering, and Technology's Committee on Education and Human Resources. These efforts emphasize providing students and their teachers with "hands on" experiences in ongoing, cutting-edge scientific and technical research.

In the period since the October 1989 Math/Science Education Action Conference held in California, the Department has developed a number of major science and mathematics education initiatives centered around our national laboratories

and research facilities and carried out in collaboration with public and private sector partners. Eight major new partnerships were established in FY 1990 and FY 1991 linking our laboratories with regional, urban, and rural districts. Perhaps the most ambitious of the partnerships is in Chicago where the Department has provided support to initiate the Academy for Mathematics and Science Teachers. This Academy, which links together all the major university, industrial, and Federal laboratories in the region, including ANL and Fermilab, has been established to reach and retrain each of the approximately 17,000 mathematics and science teachers in the Chicago public school system within the next six to eight years. This is clearly a major challenge that will require significant change in every one of the 595 Chicago schools. This effort will be a model for the science education retraining activities of other urban school systems across the country.

Other DOE-initiated partnerships include assistance being provided by scientists and engineers at the Sandia and LANL to teachers in both the Native American schools in New Mexico and Arizona and in the Albuquerque Public School System, as well as middle school teachers throughout rural New Mexico. In another partnership effort, the four DOE laboratories in the San Francisco region (Lawrence Berkeley, Lawrence Livermore, Sandia-Livermore, and the Stanford Linear Accelerator Center) have established a working partnership with the Oakland Unified School District to assist in a major restructuring of science and mathematics education in the Oakland Unified School System.

The FY 1992 budget request of $48.9 million for University and Science Education reflects the Secretary's and the Department's commitment to science

and mathematics education. (Table 4) This request will broaden support for university faculty/student research appointments, increase the number of participants in precollege education programs at DOE laboratories, and continue the laboratory rural/urban partnerships programs.

The Laboratory Cooperative Science Centers subprogram, with a request of $27.6 million, will provide support for comprehensive programs at the national, regional, and local level at the DOE laboratories. This includes: (1) summer and semester-length research appointments for undergraduate science, mathematics and engineering students; (2) summer and academic year appointments for university faculty and graduate students; and (3) support for precollege student and teacher research appointments, including the prestigious DOE High School Science Students Honors Research program. The budget request also includes support for precollege mathematics science education initiatives and support for a number of rural/urban school partnerships, including the partnerships mentioned earlier.

The University Programs subprogram, with an FY 1992 request of $7.7 million, will continue to provide cost-shared support for the development of travelling museum exhibitions and related classroom educational materials. Support is also requested to continue the expansion of the Prefreshman Enrichment Program to involve 7,000 middle school students (predominantly women and minorities) in summer workshops on mathematics, science and engineering conducted by universities on their campuses. Continued analyses of manpower in energy-related fields are also supported. A new initiative is proposed to retain women and minorities in the math/science pipeline who are interested in

Table 4
Energy Supply R&D
University and Science Education
Budget Authority
($ in millions)

	FY 1990	FY 1991	FY 1992 Request
Operating Expenses			
Laboratory Cooperative Science Centers	$ 11.6	$ 24.0	$ 27.6
University Programs	6.8	11.9	7.7
University Reactor Fuel Assistance	4.0	3.2	3.7
University Research Instrumentation	4.9	4.9	5.0
R&D Laboratory Technology Transfer	2.2	2.6	4.9
Total University and Science Education	$ 29.5	$ 46.6	$ 48.9

careers as pre-college science or mathematics teachers. Finally, the request also includes support for DOE laboratory alliances and partnerships with minority universities and colleges.

The FY 1992 University Reactor Fuel Assistance subprogram will continue to provide support for refueling and related activities for university nuclear research and training reactors. The request of $3.7 million also provides continued support for the conversion of university reactors to Low Enriched Uranium.

In FY 1992, the University and Science Education program includes the University Research Instrumentation subprogram. This subprogram is also directed at strengthening the Nation's science and education infrastructure by helping university scientists acquire the state-of-the-art instrumentation that is needed to conduct long-range research on energy problems. In the process, the program provides graduate students with hands-on experience in the use of this sophisticated research equipment. This annual, competitive program involves substantial cost sharing from the institution receiving the equipment. The FY 1992 request of $5.0 million will assist universities in purchasing instruments that cost over $100,000 each and will be used by a number of researchers, including students. In selecting approximately 20-22 proposals to be funded, special emphasis will continue to be placed on innovative instrumentation needed to carry out advanced research on selected topics in energy-related areas.

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As the largest DOE sponsor of civilian research programs, ER has a major role to play in efforts to improve technology transfer. In FY 1992, The R&D Laboratory Technology Transfer program, with a request of $4.9 million, will continue its traditional activities of coordinating technology transfer activities and opportunities from the R&D laboratory system. In addition, a new program is being initiated to support cost-shared Cooperative R&D Agreements (CRADAs) between industry and ER's laboratories. These CRADAs will support research to enhance the commercial application of generic "spinoff" technologies arising at the ER laboratories. The CRADA program builds on the experiences of the high temperature superconductivity pilot centers, which are generally regarded as outstanding successes in obtaining U.S. industry involvement in jointly sponsored R&D. Every effort will be made to pursue the development of collaborative relationships with industry leading to CRADAs, licensing agreements, and other types of technology transfer. This program will be an important component in fulfilling ER's commitment to the implementation of the National Competitiveness Technology Transfer Act of 1989.

MULTIPROGRAM ENERGY LABORATORIES--FACILITIES SUPPORT

Timely rehabilitation and replacement of general purpose facilities at ER's laboratories is critical to achieving the goals stated in the National Energy Strategy. General purpose facilities are those that are general use, service or support. They include administrative space, cafeterias, general office/laboratory space, utility systems, roads, etc. The general purpose facilities (GPF) at the laboratories represent a multi-billion dollar

investment in infrastructure, but they are an average of 30 years old and require systematic rehabilitation and replacement in order to support the laboratories' R&D missions in the 1990's and in the 21st century.

The larger GPF requirements of the ER laboratories (i.e., construction projects with a total estimated cost of $1.2 million and above) are addressed in the Multiprogram Energy Laboratories - Facilities Support program. This program funds larger construction projects that counter problems of aging and obsolescence, and carries out ER's responsibilities for correcting environment, safety and health inadequacies in GPF. (Smaller construction projects, also called general plant projects, are funded separately via R&D program budgets.) The FY 1992 request for $23.9 million in construction funds will allow us to continue or complete 13 on-going projects in accordance with their approved schedules and to initiate nine new projects. These new projects include: two building rehabilitations, one building replacement, one fire safety project and five utility projects.

ADVISORY AND OVERSIGHT PROGRAM DIRECTION AND POLICY AND MANAGEMENT

The FY 1992 budget request for Advisory and Oversight Program Direction is $10.1 million. The FY 1992 request will provide the staffing resources required by the Director of Energy Research to carry out his responsibilities under legislation (P.L. 95-91) and those assigned or delegated by the Secretary in areas beyond the scope of other ongoing Energy Research programs. These funds are required to provide for the salaries, benefits, travel, and other expenses associated with 74 full-time equivalent employees. This

includes support for expanded environment, safety, and health oversight responsibilities. It also provides the staffing resources required by the recently established Office of the Secretary of Energy Advisory Board (SEAB) to assist the Secretary in Departmental decisionmaking.

The FY 1992 request for Policy and Management is $1.2 million. These funds are required to provide for the salaries and related expenses associated with 10 full-time equivalent employees in the Office of the Director of Energy Research.

This concludes my testimony. I would be happy to answer questions.

Mr. ROEMER. Thank you, Dr. Decker, for that insightful testimony, and for abbreviating some of it so that we can ask some questions, too. I know you have got a lot to say.

Before beginning the questions, if any member wishes to submit additional remarks, they will be included in the record. Without objection, so ordered.

Dr. Decker, other than the Advanced Neutron Source, what other major construction projects will be under consideration for funding within Basic Energy Sciences between now and 1995?

Dr. DECKER. These are new ones that are not presently under construction. I can't think of a list offhand. There is a Combustion Dynamics Initiative that Sandia and the Berkeley Laboratory are planning to propose. I can't think of any others offhand.

There is some instrumentation to be used on the two research reactors that have been proposed.

Those are the only two things that come to mind offhand.

Mr. ROEMER. If there are additional ones, could you just submit those for the record?

Dr. DECKER. I would be glad to

Mr. ROEMER. That would be great. Thank you.

[The information follows:]

No other construction is planned in the foreseeable future.

Mr. ROEMER. What is the expected useful life of the High Flux Isotope Reactor?

What about the High Flux Beam Reactor?

Dr. DECKER. The useful life of the High Flux Isotope Reactor is probably in the range of maybe five to ten years would be a guess. We are making regular tests on that reactor, checking for integrity of the pressure vessel. Based on those tests, we will decide how long the reactor can operate safely.

Mr. ROEMER. We hear that a national initiative for material sciences is in the early stages of discussion.

Is the Department of Energy going to participate in this formulation? If so, how?

Dr. DECKER. There is not, to my knowledge, any activity within the Executive Branch to put such an initiative together at the present time. It has been discussed. It may, in fact, occur. I can assure you that we will be a significant player in any activity of that type, should it occur. We are strongly represented in the relevant White House committees, the FCCSET committees, that would be putting together any such initiative.

Mr. ROEMER. Dr. Decker, as you probably know, this committee is seeking support for the SSC, the space station, and now the Advanced Neutron Source. There has been some discussion about the Burning Plasma Facility.

Are we prepared to reciprocate in the not-too-distant future?

Have we thought this policy through to its logical conclusion?

Dr. DECKER. The question is: With regard to international participation, are we prepared to participate in the projects of other countries?

Mr. ROEMER. That's right.

Dr. DECKER. Yes. I think we have to be prepared to do that. I think we have to be prepared to reciprocate if we expect other na-

tions to become involved in major scientific projects that are initiated by the United States. Then I think in order to maintain a credibility, yes, we would have to participate in good projects that may be proposed by other countries.

Mr. ROEMER. At what level, and from whom, would you seek to get this international support and cooperation?

Dr. DECKER. I don't think that we have any projects that have been proposed to us, other than first, there is the International Thermalnuclear Engineering Reactor, which is a four party international arrangement, which is not really the project of any one country, but is rather the joint effort of the four equal partners. We have been participating in that for several years and will probably continue to do so.

There is one other project where we have been approached. That is on a facility, which is called a KAON facility that Canada has under consideration. But Canada has not decided to move forward with that project themselves at this time. I think that decision is near, but they haven't made a decision. But they would like us to participate.

Mr. ROEMER. Getting into the field of user facilities, Dr. Decker, you say there are about 2,800 users at seven large user facilities.

How exactly would you break these down in terms of academic, laboratory and private users?

Dr. DECKER. It is about one-third university, one-third laboratory and one-third industry.

Mr. ROEMER. I have finished my questions. I would like to yield to our Distinguished Ranking Member.

Mr. MORRISON. Thank you, Mr. Chairman.

Dr. Decker, I know you folks really get squeezed when some of your requests get to the OMB, as in this budget preparation.

Could you speculate for us what are the principal areas where you believe additional funding could be utilized, particularly in material science research?

If you could write your own ticket, where would you go?

Dr. DECKER. Mr. Morrison, I think we are in a situation of a very tight budget where all of our research programs are pretty much equally squeezed. They are all very tight. Many of them do not have cost of living increases going from 1991 to 1992. So there is sort of a general squeeze that we feel within the Office of Energy Research. That is certainly true of Materials Research.

Mr. MORRISON. I don't want to get you in trouble, but are there areas that you sense would reflect a greater need that you would really like to pursue? I mean we have a little bit of flexibility here more than you have. It is helpful to us if we sense that there are some potentials out there that we are not responding to as a Nation.

Dr. DECKER. What we have done in the 1992 budget request is to try to bring forward some initiatives within the Energy Research programs. One of them is in the BES budget in the high performance computing area. So we have tried to take care of one area, which we believe is a high priority.

Dr. IANNIELLO. Within the funds that we have, we have tried to emphasize an area that the National Academy of Sciences has highly recommended. That is the area of materials synthesis and

processing. But there are many that are still underfunded. Within the funds that are available, we think we have a pretty balanced program.

Mr. MORRISON. But you could do a lot more if you had the flexibility to deal with it?

Dr. IANNIELLO. I think that is always the case.

Mr. MORRISON. Always, yes. One of the areas that has been prioritized lately. In fact, we noticed in the National Energy Strategy that it was emphasized and wondering what sort of response would you give in the environmental related materials question. What level of funding do you need to begin to get technologies developed to remediate or address the waste problems just in the Department of Energy.

Dr. DECKER. In our Biological and Environmental Research Program, we have, I think, about $12 million or so that is devoted to very basic research related to environmental restoration. There is also some effort within the Basic Energy Sciences Program that Dr. Ianniello might talk about.

Dr. IANNIELLO. We have proposals and work under way in the chemical sciences area, in the geosciences area and the material sciences area that relate to environmental restoration and waste management. We presently have at PNL probably about $4 million or $5 million in that area.

Mr. MORRISON. I suppose we can anticipate that because of the importance of defense waste clean-up, for instance, there will be expanded investments in this research area.

Dr. IANNIELLO. Yes. We have had meetings and workshops to develop the ideas that would underpin the research that we would like to do.

Mr. DECKER. There is also, I should point out, money for research within the Environmental Restoration Budget of the Department under Leo Duffy.

Mr. MORRISON. How is that coordinated with what you do, Dr. Decker?

Dr. DECKER. We have, I think, a fairly clear division of responsibilities where Mr. Duffy's programs support a rather applied research and we try to support him and his activities with our basic research programs. We do have regular interactions with them to try to coordinate our activities.

Mr. MORRISON. Is it likely that his need for technological applications will drive the Basic Energy efforts that you make, or will it go the other way or be a mix?

Dr. DECKER. We'll see some of both.

Mr. MORRISON. Let me shift directions just very quickly, Mr. Chairman, for a question that I think is important to this subcommittee. That is our campus-based research reactors, university operated.

Is there light at the end of the tunnel on that?

I know that you have some studies that have been ongoing with some recommendations.

Can we keep those reactors going?

Should we plan at some point for a center that people would come to or that adequate facilities would be available?

Does the Department have a long range view on this issue?

Dr. DECKER. We do not provide direct funding support for those university reactors. That is, we don't provide support for their operation. What we do do is to provide fuel for those reactors.

We are currently in the process of converting all of the university reactors to low enriched uranium fuel. I believe that at least all of the plate-type reactors will either have been converted or we will have the fuel to convert them by the end of fiscal year 1992.

We have another program called reactor sharing where we do provide money for university professors and students who are at a university that does not have a reactor to go do research at, say, MIT, or one of the universities that does have a reactor.

That, right now, is the extent of the Department's funding, I believe, of the university reactor programs.

Mr. MORRISON. I noticed a significant decline in the number of university based reactors, from 76 down to 40 in the last 20 years.

Can we stand by and let that happen to us?

Perhaps the Department is going to have to play a more significant role in that?

Dr. DECKER. I think that is a fairly complicated question from what I know about it. I think that there are at least a couple of reasons why the number of university reactors is declining. At least, I can think of three. One is financial. They have had difficulty in finding the money to operate these reactors. That is tied, in part, to the fact that nuclear engineering departments in many universities are in decline. In fact, a number of them have essentially gone out of business.

Then I am sure there is another factor, which is the public perception of having reactors of any type in populated areas. I am sure that has been a factor in closing some of them. I am sure it was in closing the UCLA reactor.

Mr. MORRISON. Perhaps an option would be to utilize a Department of Energy facility. I have a great one in mind, namely the Fast Flux Test Facility. It has a place with both the fast reactor and a light water reactor side by side. We'll talk about that sometime.

Thank you.

Thank you, Mr. Chairman.

Mr. ROEMER. Just to follow on that insightful questioning, Mr. Morrison.

Who has the responsibility, then, Dr. Decker, for once a facility or reactor is closed, what is the next step?

Dr. DECKER. Once it is closed?

Mr. ROEMER. Yes.

Dr. DECKER. In the case of the university reactors, since DOE does not own them, they are operated by the universities under license by the Nuclear Regulatory Commission. I believe the universities have the responsibility for decommissioning and decontamination.

Mr. ROEMER. Thank you. Mr. Cramer.

Mr. CRAMER. Thank you, Mr. Chairman.

Dr. Decker, I will kind of take my opening statement in now and go a step further. Most of the Basic Energy Sciences subprograms have significant funding for university research. For example, it is my understanding that 86 percent of the energy biosciences is uni-

versity funded; 45 percent of the engineering and geosciences efforts are at universities.

How are these universities selected?

Dr. DECKER. They are selected through a peer review process. There is a notice that goes out from the Department. It is published in the Federal Register that indicates the areas of research in which we are interested. University proposals come in in response to that announcement. Then they are evaluated by peer review. In some cases, we have put out special announcements for certain programs. I believe, in fact, we put one out in the energy biosciences area.

Mr. CRAMER. Can you think off the top of your head of maybe two or three universities that maybe receive the most of such funding? Are there any that stand out?

Dr. DECKER. I don't have those figures in my head, but I would guess that we probably have quite a few funds at MIT, and various campuses of the University of California, but I would rather provide you a list for the record.

[The information follows:]

The following 13 universities receive the most funding within the Basic Energy Sciences program:

FY 1990 funding

	Thousands
California Institute of Technology	$1,704
Cornell University	3,281
Georgia, University of	2,996
Harvard University	1,639
Illinois, University of	9,260
Kansas State University	1,659
Massachusetts Institute of Technology	5,341
Michigan State University	2,957
Northwestern University	2,144
Notre Dame, University of	3,316
Purdue University	3,729
Stanford University	13,997
Wisconsin, University of	1,911

Mr. CRAMER. Thank you. I wish you would do that. That is only fair. I am, of course, curious as to how this works.

How might a university that is not currently funded qualify? Would that simply be by getting the Federal Register, submitting a proposal that could be properly scored?

Dr. DECKER. Yes. We are receptive to proposals at any time from universities. I would encourage a university that wishes to obtain research money from us to talk to the appropriate program manager within our offices. I think that discussion will help them in preparation of a proposal, to guide them in the right directions and into areas that we have a particular interest perhaps.

Mr. CRAMER. How many historically black colleges and university are directly involved in any of the subprograms?

Dr. DECKER. I don't have that number offhand, but I can certainly get it for you.

Mr. CRAMER. Thank you.

[The information follows:]

In FY 1990 there were 42 Historically Black Colleges and Universities, HBCUs, supported by all DOE programs totalling $15.7 million. Contributing programs amounts follow:

	Millions
Energy research	$6.8
Fossil energy	.7
Defense programs	1.9
Conservation and renewable energy	.7
Environmental restoration and waste management	4.0
Nuclear energy	.4
Minority economic impact	.8
Other	.4
Total	15.7

Dr. DECKER. I saw a list recently, and I just don't recall the numbers. We have had a problem in getting good research programs from historically black colleges. We have had some outreach efforts to try to do that. We think that is important to do.

Mr. CRAMER. I appreciate and applaud that, and would like to see more of that happen.

Along that line, how can an institution that has a limited endowment base build the reputation to get into this game, so to speak? Are they at a disadvantage when they apply?

Dr. DECKER. I think the key is really hiring some quality scientists who can then generate the good scientific proposals. I won't tell you that they are not at a disadvantage. Financial resources always help. In order for a university to build up a capability and to obtain more research funding from any source, it really starts with the people. They really need to hire a good scientist.

Mr. CRAMER. I ask these questions because the demographics indicate that minorities will become an increasingly important source of talent for our future scientists and engineers. It seems important that we begin now to build that base. So I applaud any emphasis on that subject matter.

Thank you, Mr. Chairman.

Mr. ROEMER. Thank you, Mr. Cramer.

Mr. Fawell.

Mr. FAWELL. Thank you, Mr. Chairman.

Dr. Decker, I know the Department is considering changes in its fee policy and user fees, which I think was part of the so-called deficit reduction bill that we passed. Where is the Department in that regard now? No decision, I gather, has as yet been made on an overall plan.

Dr. DECKER. Mr. Fawell, we were required by the Congress to look at our user fee policy. That is being done by the Controller's office within the Department. That study has not been completed. We have not made any decisions that would affect our facilities at this time.

Mr. FAWELL. I was thinking especially in terms of something like the Advanced Photon Source, for instance. Any general ideas as to whether that would be a positive aspect or would do more harm than good or any views that you have?

Dr. DECKER. We have had a policy of charging user fees for proprietary work—work which generally a company wants to perform, and does not wish to publish the results in the open scientific liter-

ature. That policy, I am sure, will continue. I don't see any reason to change that.

All other users have not been charged a user fee. If we were to institute a user fee, and I don't want to indicate that that is the direction we are headed, it becomes complex to manage without a doubt. We would have to look at all aspects of the difficulties introduced by levying fees before heading down that path It is not an easy thing to do.

Mr. FAWELL. I mentioned the Advanced Photon Source. Again, we, in our area, highly evaluate that tremendous potential facility which is now in the process of being constructed. We note, for instance, this year, that the construction costs that have been the Administration request is about $1.6 million less than has been anticipated as being the amortized cost over a six-year period.

Each year for, I think, three years now, there has been a shortfall in the construction costs—not large, and a shortfall in the support R&D. So it adds up at this point cumulatively to about $13.5 billion.

I say this with full acknowledgement that you at DOE have got tremendous problems trying to satisfy everyone, but it would appear to me that if the shortfalls continue each year, we may be adding a year to the construction time period here.

Has there been much attention paid to this, do you know?

Contemplating that we are going to try to bring these shortfalls up, if not this year, perhaps next year when probably the debt will be worse?

Dr. DECKER. We have, just within the last couple of months, had a thorough review of that project. I am pleased to say that that project is going very well on both cost and schedule. Technically, it is going well. There was a cut of $5 million to the construction budget by Congress in fiscal year 1991. That does, I think, introduce a small delay in the schedule. It is not major. I think it is about a couple months, something like a couple of months.

We have not increased the TEC of the project due to that cut. We assume that we are going to get that money back in the out-years. But because of savings that have been realized within the project, I am pleased to tell you that we have not increased the TEC, even though we did get that cut last year in the Congressional budget.

Mr. FAWELL. Just one other question. I notice in your printed testimony in reference to the various areas under the Basic Energy Sciences, that the material sciences have sustained a relatively, compared to the others, larger cut from $274.9 million enacted to $257.1 million request. Nobody made out famously well in any of the categories, but I noticed that this was a pretty steep cut; yet materials sciences is certainly extremely important. Why was that?

I noticed in 1991, apparently, there was an appreciable increase over 1990. Are you just trying to even things out?

Dr. DECKER. Mr. Fawell, that is a little more complicated story than the budget numbers indicate on the surface. There was not an actual cut in research in materials science. The reason that the budget goes down is that there were a number of projects that were added in the appropriations process, which were accounted for within the materials science programs. I forgot which ones they were, but university buildings and that sort of thing. They appear

in the 1991 column, but we did not request any continuation of funds for those projects, so they don't appear in 1992.

Mr. FAWELL. I see. So as far as the other projects are concerned, they are relatively even or fairly gaining.

Dr. DECKER. Yes.

Mr. FAWELL. Thank you.

Mr. ROEMER. Thank you, Mr. Fawell.

Dr. Decker, just following up on Mr. Cramer's line of questioning, if you could provide to us in writing those contact points, I would appreciate that.

Dr. DECKER. I would be glad to do that.

[The information follows:]

University personnel can contact the following Basic Energy Sciences managers for more information regarding submission of proposals:

Dr. Louis Ianniello, Acting Associate Director, BES (Telephone: 301-353-3081)

Dr. Iran Thomas, Director, Materials Sciences Division (Telephone: 301-353-3427)

Dr. Robert Marianelli, Director, Chemical Sciences Division (Telephone: 301-353-5804)

Dr. Walter Polansky, Acting Director, Advanced Energy Projects Division (Telephone: 301-353-5995)

Dr. Robert Rabson, Director, Energy Biosciences Division (Telephone: 301-353-2873)

Dr. James Coleman, Director, Engineering & Geosciences Division (Telephone: 301-353-5822)

Dr. John Cavallini, Acting Director, Scientific Computing Staff (Telephone: 301-353-5800)

Mr. ROEMER. Now anybody in the room attending their first hearing would be utterly confused by my next statement. Madame Chairperson, I will yield the gavel and questions.

Mrs. LLOYD. Thank you very much, Mr. Roemer. I think everyone in the room is pretty much aware that we are very excited about the new members on our committee this year. I am delighted to have Mr. Roemer and Mr. Cramer to be here. I am expecting great things from them as new members.

I am especially pleased with their interest in the affairs of this subcommittee. They have not only attended the meetings, they have met with me in my office and with the staff to have a better knowledge of the programs before this committee.

Certainly, there are no more important issues before the Congress than we are looking at today if we are going to broaden our energy technology base for now and for the future as well.

So I want to thank you for your interest and for chairing the hearings. I am proud of both of you.

Dr. Decker, according to your testimony, the Advanced Neutron Source will complete conceptual design next year. Then do you plan to move directly to a construction phase status in the following year in 1993?

Dr. DECKER. We have not made that decision yet. We will be making that decision in the process of developing our 1993 budget request. The next step might be a design only line item in the budget. That is a possibility.

Mrs. LLOYD. As you know, I am very anxious to move to a construction phase. It has been so long since we have had a new construction project, if for no other reason. Certainly, you recognize the great need for this facility. I would urge you to try to get the Department to move as rapidly as possible on this program.

How much money have we put into ANS at this point?

Dr. DECKER. I don't know the total. Our request for fiscal year 1992 is $24.6 million to complete the conceptual design. I do not know the total that we have put in over the years for research and development and design.

Mrs. LLOYD. How long do you anticipate it will take to complete construction on this program?

Dr. DECKER. It is probably a seven-year or eight-year project.

Mrs. LLOYD. As you know, I am very interested in the science and the math programs that your Department has jurisdiction over. I think there is very promising efforts in this field. But I am a little bit confused that we are pushing science and math education as one of the Secretary of Energy's top priorities. At the same time, it seems as if we are killing the nuclear energy research and education program. Would you explain that for me?

Dr. DECKER. Mrs. Lloyd, we are——

Mrs. LLOYD. Is it hard to explain?

Dr. DECKER. We are carrying, I think, $2.5 million in the nuclear energy budget for nuclear engineering fellowships. We are not carrying funds in the Office of Energy Research. It was a matter of budget priorities. Within our science education program, we have put our highest priority on trying to deal with the part of the system which we feel is in most need of repair. That is in the K through 12 area.

Mrs. LLOYD. Would you repeat that last statement?

Dr. DECKER. In our science education programs, we are putting our priority, and have for the last couple of years, on trying to fix some of the problems associated with the younger students, essentially, in the K through 12, trying to do some things to train teachers and work with local school systems. That has been our emphasis. That is in line with the Executive Branch initiative in Science Education. That was the top priority. Because of the tight budget situation, we just do not have the funds to continue on with additional programs in nuclear engineering.

Mrs. LLOYD. Don't you think it is essential that we train more nuclear engineers at this point? Aren't we facing a shortfall?

Dr. DECKER. Yes. We are concerned about that. As I indicated, the nuclear energy program does have, I think, $2.5 million for fellowships in their budget.

Mrs. LLOYD. Do you feel this is adequate?

Dr. DECKER. I think it is a very good start on the problem, yes.

Mrs. LLOYD. I think that there is a logical analogy as what we have just witnessed in the Persian Gulf. We have seen the highly sophisticated equipment that we have all been so very impressed with. At the same time, this equipment didn't work because somebody put a quarter in it; it worked because of the highly trained men and women. The same thing is going to be true in our nuclear engineering program. We are going to have to have the people to take care of the equipment to make this work.

Dr. DECKER. Yes. That is certainly true.

Mrs. LLOYD. I would urge you to give this greater consideration.

I want to ask you about the university research reactors. As you know, some of them are going to need upgrading and modernization. What is the Department's feeling on continuing to help with

this reactor? It is my understanding that universities can't afford to upgrade and modernize this program.

Dr. DECKER. We have a couple of programs associated with the university reactors. One is that we provide the fuel. As I mentioned before you came in, we will have converted I guess, seven of the university plate-type reactors by the end of this fiscal year. We will have fabricated the fuel to convert the remainder of those reactors by the end of fiscal year 1992.

We also have about half a million dollars worth of funding for what we call reactor sharing, which provides funds for university professors and students at a university that does not have a reactor to go use a reactor at a school that does have one. That right now is the extent of our funding request for university reactor programs.

Mrs. LLOYD. Well, I want to thank you for the good work you are doing and for how well you serve our country. I would like to state, as Admiral Watkins stated, that there will be a revival of nuclear energy in the coming decades. If this is true, it is in the national interest to train nuclear engineers and to maintain our university reactors. Thank you.

Mr. ROEMER. Thank you, Madame Chair. I was going to tell you your time had expired, but I was going to say it with a smile, too, just to tease you since I don't get this perspective very often. In speaking for Mr. Cramer, too, thank you for your very generous comments and your leadership on this subcommittee and in the United States Congress as well.

Dr. Decker, Dr. Ianniello, thank you for your valuable time and your expert testimony. We will be submitting some questions to you, which we hope you respond to for the record.

Madame Chairperson will be welcoming the second panel.

Thank you very much.

Mrs. LLOYD. Before I do welcome the second panel, I would like to remind the witnesses that your entire written statement will be made a part of the hearing's record. Without objection, so ordered.

I also would like to remind the witnesses that you may summarize your testimony in five minutes, and that way, we will have more time for questions and discussion with the members.

Our second panel will be speaking on advanced reactors and nuclear engineering education. Testifying today are Dr. Marcus Voth, Associate Professor of Nuclear Engineering at Pennsylvania State University, and Dr. Barclay Jones, Professor and Head of the Department of Nuclear Engineering at the University of Illinois.

We welcome you today.

Dr. Voth, you may proceed.

STATEMENT OF DR. MARCUS H. VOTH, ASSOCIATE PROFESSOR OF NUCLEAR ENGINEERING AND DIRECTOR OF THE RADIATION SCIENCE ENGINEERING CENTER, PENNSYLVANIA STATE UNIVERSITY

Dr. VOTH. Thank you, Madame Chairman, members of the committee.

I am Marcus H. Voth, Associate Professor of Nuclear Engineering and Director of the Radiation Science and Engineering Center

at The Pennsylvania State University. I am also the chairman of the University Reactor Support Committee, which is a committee of the National Organization of Test, Research and Training Reactors, the Nation's composite of 37 operating university research reactors.

This testimony is submitted on behalf of the TRTR. We are requesting jointly with the Nuclear Engineering Department Heads Organization, which my colleague, Dr. Jones, represents, a total of $17 million in the fiscal year 1992 budget for nuclear education and university research reactor programs.

With your permission, I request that my complete written testimony, which I will summarize here, be submitted for the record.

Mrs. LLOYD. Without objection, it will be. Thank you.

Dr. VOTH. Thank you.

Let me begin my statement by saying that TRTR is particularly appreciative of the monies that your committee has been instrumental in getting into the fiscal year 1990 and fiscal year 1991 budget. There has been $1 million put in each year, which has been very effective in upgrading the instrumentation at University Research Reactors.

Secondly, I would like to, for the sake of the record, make a quote from the recent National Research Council study, which was completed in 1988 entitled, "University Research Reactors in the United States—Their Role and Value."

The conclusion of that report states that policies that will limit closures and encourage modernization of a substantial subset of existing reactors sufficient in numbers and types to meet National Academic needs for research, education and service are clearly in the National interest. It is in that pursuit that I address the committee here today.

Despite recent efforts, the number of operating university research reactors has declined from 71 to 37, as of today. They are declining at the rate of approximately two per year.

I would like to make the distinction that, while university engineering programs are a significant user of university research reactors, they are not the only and they are not the major users of our facilities. University research reactors are used in the fields of physics, chemistry, biology, medicine, epidemiology, environmental sciences, material sciences, fluid mechanics, geology, oceanography, agriculture, forestry, archaeology, paleontology, forensic sciences, energy production—just to mention a few of the areas.

Some of the specific applications that we provide to this multiplicity of disciplines include radioactive tracer labelling, neutron activation analysis, neutron scattering and neutron radiography. Some of the breakthroughs in those areas have involved things like characterization of lunar samples, identification of aerosol complements and arctic haze, measurements of depolarization of single crystal superconductors, understanding trade routes of pre-hispanic Mexico, DNA sequencing and molecular biology experiments.

Unfortunately, most of the United States university research reactors were built in the 1950s and the 1960s. Construction was made possible through substantial Federal financing. The subsequent operating expenses have been borne by host institutions.

Today, to remain technologically competitive, those facilities require replacement, modernization and upgrading of equipment.

Our group has recently attempted to assess the value and the true costs associated with this set of experimental facilities. Preliminary indications from that study have come up with some remarkable numbers, I feel. If we look at reactor operations only, just the cost of operating reactors, we are talking about $9 million for the entire set of university research reactors in the United States. Of those operating expenses, 85 percent are borne by host institutions. Twelve percent are borne by the Department of Energy through the Fuel Assistance Program, which Dr. Decker spoke of. Three percent comes from private industry.

In terms of the overall research programs conducted at these facilities, again, a surprisingly small number of $30 million for the entire set of university research reactors. With that $30 million, which includes the research programs that are done by the users using the facility, the teaching that is conducted at the facilities, as well as support to private industry and government institutions, much of which is supported by user fees, we see a total expenditure annually of $30 million.

We feel that these numbers are very small numbers relative to the return technologically that they give our country. Of that $30 million, approximately half of it comes from host institutions. A quarter of it comes from private industry. We find 11 percent of it coming from the Department of Energy, and 10 percent coming from other Federal agencies.

One thing I would like to do is respond to a specific inquiry from your staff asking me to comment on where within the administration we would like this funding to be channeled or routed. I don't wish to usurp the responsibility of the Congress or of the administrative agencies, but let me simply comment on our experience with funding.

The Department of Energy and its predecessor agencies have been the long time sponsor of any money that has come toward university reactors. They have administered the University Reactor Fuel Assistance Program and the University Reactor Sharing Program, which you have heard Dr. Decker talk about. More recently, within the last two years, with these two special authorizations, this group has administered the University Reactor Instrumentation Program. Specifically, this has been done under the University and Science Education Office within the Office of Energy Research.

We find that the University and Science Education Office has developed an understanding of universities. It has resulted in excellent program administration. There has been peer review of proposals. There are annual performance reviews. There is a general accountability of Federal expenditures. Furthermore, the diversity of disciplines that are represented by the University Research Reactor Programs appear to be best served by a group that has a general university perspective as opposed to any other programmatic mission.

Our final comment is quite logically that we believe the programs in support of University Research Reactors can be adminis-

tered most effectively in the Office of Energy Research based on our past experience.

In conclusion, I would like to say that the University Nuclear Engineering Programs and Research Reactor Facilities serve vital roles in assuring our Nation's energy supply, providing graduates for key roles in areas vital to the National security, and in undertaking the lead into research critical to our competitiveness in high technology areas in the international marketplace. We believe the economic programs and the reactor facilities merit the consideration in support of your committee.

I sincerely appreciate the opportunity to present testimony on this important subject.

[The prepared statement of Dr. Voth follows:]

Testimony

Presented to the

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

SUBCOMMITTEE ON ENERGY

By

Marcus H. Voth, Ph.D., P.E.

Associate Professor of
Nuclear Engineering
and
Director of the Radiation Science Engineering Center
The Pennsylvania State University

and

Chairman of the University Reactor Support Committee

of the

NATIONAL ORGANIZATION OF TEST, RESEARCH AND TRAINING REACTORS

March 19, 1991

Madam Chairman, Members of the Committee, I am Marcus H. Voth, Associate Professor of Nuclear Engineering and Director of the Radiation Science and Engineering Center at The Pennsylvania State University. I am also chairman of the University Reactor Support Committee of the National Organization of Test, Research, and Training Reactors (TRTR). This testimony is submitted on behalf of the National Organization of Test, Research, and Training Reactors (TRTR) requesting support of $17 million for FY 92 for Nuclear Engineering and University Research Reactor Programs administered through the Department of Energy Office of Energy Research. This request, which is presented in the form of a proposed budget, was jointly developed with the Nuclear Engineering Department Heads Organization (NEDHO). With your permission, I request that my complete written testimony, which I will summarize here, be entered into the record.

TRTR is made up of the directors and managers of the 37 currently operating university research reactors in 25 states and focuses on the operation and utilization of these facilities. The origanization would like to express its sincere appreciation for the vision and leadership of the Committee which has resulted in support for university research reactors (URRs) at a level of $1 million per year for FY90 and FY91. The appropriation has been ably administered by the Office of University and Science Education in DOE and has had an extraordinarily positive and invigorating impact. The appropriation, along with some additional funding, has led to an expansion of the extremely effective DOE Reactor Sharing Program and has funded the acquisition of badly needed new equipment and upgrades at the research reactor facilities. In requesting that such funds again be appropriated, it is important that a clear picture of the needs of the URR facilities be presented to justify the levels of the requests.

Your attention is first directed to the recent study by the National Research Council entitled *University Research Reactors in the United States--their Role and Value.* A copy of the executive summary of the study is appended to this testimony. This study examined the roles of URRs in the areas of research, education and service, especially in light of the decreasing numbers of these reactors. The report concluded that "Policies that will limit closures and encourage modernization of a substantial subset of existing reactors, sufficient in numbers and types to meet national and academic needs for research, education and service are clearly in the national interest."

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The number of licensed URRs has declined from a total of 71 to 37 located at 33 sites. For the last several years the number of reactors has declined at the rate of two per year. This is cause for great concern, especially since these university research reactors form a fundamental and vital component in our national research infrastructure. While nuclear engineering departments use these reactors for both education and research, it is imperative to recognize that the university reactors serve a much broader user community than just nuclear engineering. Faculty and students, plus, researchers from universities and industry carry out extensive research in many disciplines at university reactor facilities. University research reactors are the focus of multidisciplinary research efforts resulting in contributions to the fields of physics, chemistry, biology, medicine, epidemiology, environmental sciences, material sciences, fluid mechanics, geology, oceanography, agriculture, forestry, archaeology, paleontology, forensic sciences, energy production and many other areas.

In education, on-campus reactors are increasingly used as laboratories by students from non-nuclear fields, as well as from nuclear engineering, radiation protection, and applied science. University reactors contribute to the education of most of the graduates who are trained in the uses of radiological techniques and serve a broad range of off-campus constituencies including the medical community, industrial organizations, and governmental agencies at both the state and federal levels.

Among nuclear engineering students, essentially all undergraduates use URRs for laboratory classes where a reactor is available. Many graduate students use URRs for classes and also for independent research. The recent National Research Council study entitled US Nuclear Engineering Education: Status and Prospects reports the following percentages of graduates known to be entering the US workforce:

	Degree		
Placement	BS	MS	Ph.D
Nuclear utility	23	30	9
Other industrial	26	20	17
Academic	4	4	26
Federal Government*	40	35	41
Other	7	11	7

* Includes DOE contractors and military

The federal government is the largest employer at all degree levels. Since in many positions the only practical, hands-on experience occurs in the academic segment of a person's career, it is vital that these young men and women receive a high quality laboratory experience in college.

Four principal techniques which are extremely powerful research tools and unique to research reactors are radioactive tracer labeling, neutron activation analysis, neutron scattering, and neutron radiography. By way of illustration, these techniques have contributed to such diverse studies as:

- Characterization of lunar samples,
- Identification of the aerosol components in arctic haze,
- Measurements of depolarization in single crystal superconductors, and
- Understanding of the trade routes in pre-Hispanic Mexico
- DNA sequencing and molecular biology applications

The national Research Council's report effectively summarizes the broad range of applications of university reactors. In this respect, URRs have made and continue to make significant contributions. Attached are papers entitled "Recent Important Contributions of University Research Reactors," and "University Research Reactors and Technological Competiveness," which attest to URR accomplishments. Further erosion in the number and status of university reactors would have a significant negative impact on our national capability to perform research and development in high technology areas and maintain a history of achievements like that documented in these papers.

Turning to specific budget recommendations, particular attention should be given to the DOE Reactor Sharing Program for which we are proposing augmented support. This program has allowed faculty and students from other universities, community colleges, high schools, and junior high schools to utilize university reactors. This has led to research projects and lines of inquiry which might never have occurred had there not been a mechanism to access these facilities. The Reactor Sharing Program must rank as one of the most cost-effective and successful expenditures of federal funds, making geographically distributed URRs effectively available to many users as unique regional resources. This program must receive continued support and should

be expanded to allow the university reactors to serve a broader spectrum and larger number of users including host institution researchers. Additional funding of $1 million, $2 million, and $3 million is proposed for FY92, FY93, and FY94 respectively.

Other countries have recognized the value of research reactors and responded vigorously. Major commitments to preserve the viability of neutron sources have been made overseas. In contrast, in the U.S., support for operations, upgrades, and equipment replacement has fallen behind, and those funds which have been available have come primarily from state and private sources. Funding for neutron sources in foreign countries over the past twenty years has been nearly a factor of 10 higher than in the U.S., and these countries are now well positioned to benefit from this investment in increasingly competitive fields of new materials and high technology. As an indication of the need that exists in the U.S. facilities, in FY90 and again in FY91 DOE issued a call for proposals for new equipment to disburse the $1 million appropriated each year for that purpose. Thirty-three institutions were eligible to submit proposals. In FY90 there were proposals from 28 eligible institutions totaling $3 million and in FY91 there were 27 totaling $2.5 million. However, these requested amounts do not accurately reflect the need for new equipment, but rather indicate restraint on the part of the research reactor community in responding to DOE's stated interest in providing support to as many institutions as possible. In fact, the TRTR leadership feels that the National Research Council's estimate of $20 million per year much more closely reflects the true overall requirements. To assure that a significant reactor equipment program continues, we recommend an increase to $3 million in FY92 and $5 million in FY93 and again in FY94.

While the need for equipment acquisitions at existing facilities is immediate, planning should also commence for major reactor upgrades during the next 5 to 10 years. Most of the university reactor facilities in the U.S. have been in service since the 1950's and 60's. Construction was made possible through substantial federal funding. The subsequent operating costs have been borne by the host institutions. To remain technologically competitive, the aging U.S. facilities now require equipment replacement, modernization, and upgrade. Host institutions cannot support both operation and modifications. Without new sources of funds for upgrades U.S. URRs suffer in comparison with newer or upgraded similar installations in Europe, Japan, the USSR, and even in emerging countries such as India. For neutron source development, about $250 million was spent in Europe. In the 1980's this situation

continued with $300 million being spent for one reactor in Japan and $110 million for one reactor in Germany. If more reactor decommissionings occur within the U.S., or if currently operating university reactors are not supported at a rational level, we will lose the research capability represented by our university reactor programs. We will then find ourselves at a major disadvantage compared with our international competitors. Furthermore, it would be prohibitively expensive to try to replace this capability by building new facilities. By far the most cost effective approach to retaining and enhancing our research reactor capability is to refurbish and modernize our existing facilities. At some point, of course, it will be necessary to construct new facilities.

To assure that a significant upgrade program can be initiated, a step-by-step approach is shown in the accompanying table consisting of $1 million for planning in FY92 followed by funds for upgrades of $3 million and $7 million for FY93 and FY94 respectively. This approach would be a significant commitment to addressing the pressing question of research reactor modernization.

As is the case with research accelerator projects in this country and with successful reactor programs abroad, support is also required for base in-house research programs. A similar approach is strongly recommended for U.S. university reactors. Such support would assure that the expertise and advanced equipment are available to permit the efficient utilization of the facilities. For example, to make full use of powerful techniques such as neutron scattering or neutron activation analysis, trained personnel and sophisticated instrumentation must be available to the researcher. It has been repeatedly demonstrated at comparable accelerator facilities or overseas reactors that appropriate funding for in-house support significantly enhances the quality of the research and the effectiveness of the installation. While $10 million annually is needed for this purpose, a budget is proposed which ramps up from $1 million to an equilibrium level of $8 million during the FY92-94 period.

The university research reactor budgetary requirements are shown in the attached proposed budget. (The NEDHO budgetary requirements are also shown for completeness.) The budget shows an expansionary research reactor program phased in over a 3-year period with $6 million in FY92, $15 million in FY93 and an equilibrium level of $23 million in FY94 and beyond. These figures are consistent with the results of the National Research Council study which recommended in 1988 an annual level

of $20 million for university reactors, but in fact identified an overall need of aproximately $35 million per year. To provide for the most efficient use of these funds, it is recommended that disbursement be based on competitive proposals subjected to the peer review process.

The proposed budget is also consistent with The National Energy Strategy released a few days ago which addressed the areas of University Research and Cost-Shared Research and Development. It states "...the Department of Energy will support the upgrade and expansion of the capabilities of the Nation's research and test reactors to strengthen university research capabilities and maintain state-of-the-art research facilities. This will allow investigators to accomplish basic and fundamental research and to train scientists and engineers on state-of-the-art research facilities...the department will develop guidelines for expanding requirements for participation by industry and others; the goal is to achieve a minimum cost-share of at least 25 percent of the department's applied civilian energy R&D programs." Our group is presently studying the funding sources for URR programs. Preliminary indications show that URR programs (reactor operation, teaching and training, academic research, academic service, non-academic service, and facility upgrades) total approximately $30 million annually with 53% of the support coming from host institutions and other state sources, 23% from private industry, and 11% from DOE with an additional 10% from other federal agencies. Of the federal support, the majority is earmarked for sponsored research using URR facilities with only a very small portion being available for facility operation and equipment upgrade. Operating expenses only for the 30+ URRs are approximately $9 million annually with 85% of support coming from host institutions, 12% from DOE as reacter fuel, and 3% from private industry. A copy of this study will be submitted to your Committee as soon as it is completed. If federal support is increased as proposed and there are no other increases in non-federal support, the cost-share from non-federal sources would still be twice the DOE minimum guidline. However, if federal funding is available for significant equipment upgrades and new research programs, additional utilization and non-federal support can certainly be expected to follow.

The Committee has specifically requested comments on the recommended path of federal funding for URR programs. While TRTR does not wish to interfere with Congressional or Administrative agency decisions, we are pleased to critique our observations and experiences. The Department of Energy and its predecessor

agencies have administered the University Reactor Fuel Assistance Program and the University Reactor Sharing Program through the Office of University and Science Education in the Office of Energy Research. Most recently that office has also administered the University Reactor Instrumentation Program. The proposed programs are either similar to or expansions of these existing programs. The Office of University and Science Education has developed an understanding of universities, resulting in excellent program administration, peer review of proposals, annual reviews of performance, and accountability of federal expenditures. Furthermore, the diversity of disciplines among URR users appears to be better served by a group with a general university and science education mission than a group with any other programmatic mission. TRTR therefore believes that programs in support of URRs can be administered most effectively under the Office of Energy Research.

University nuclear engineering programs and research reactor facilities serve vital roles in assuring the nation's energy supply, in providing graduates for key roles in areas vital to national security, and in undertaking leading edge research critical to our competitiveness in high technology areas in the international marketplace. We believe the academic programs and the reactor facilities merit the consideration and support of the Committee. I sincerely appreciate the opportunity to present testimony pertinent to this important national issue.

PROPOSED BUDGET
U.S. Department of Energy
Office of Energy Research
Office of University Programs
Nuclear Engineering and University Research Reactor Programs

FY91-94 ($ Million)

	FY91 Requested	FY91 Funded	FY92 Requested	FY93 Requested	FY94 Requested
Ongoing Research Projects	4.0	2.7	2.5	5.2	8.0
New Research Projects	4.0	1.2	4.0	4.0	5.0
DOE Nuclear Engineering and Health Physics, Ph.D. Fellowship (10 new, fully-funded for four years)	1.0	0.4	1.0	1.0	1.0
Minority Institutions Program	1.0	0.2	1.0	1.0	1.0
DOE Traineeship Program	1.0	0	2.5 (NE)	2.5 (NE)	2.5 (NE)
Subtotal (NEDHO)	(11.0)	(4.5)	(11.0)	(13.7)	(17.5)
Expanded Reactor Sharing Program	1.0	0.5	1.0	2.0	3.0
Reactor Equipment Modernization	3.0	1.0	3.0	5.0	5.0
Reactor Upgrade	1.0	0.0	1.0	3.0	7.0
Reactor-based Research Programs and Operations	1.0	0.0	1.0	4.0	8.0
Subtotal (TRTR)	(6.0)	(1.5)	(6.0)	(15.0)	(23.0)
TOTAL	17.0	6.0	17.0	28.7	40.5

University Research Reactors in the United States - their Role and Value

Prepared by the
Committee on University Reseach Reactors
Energy Engineering Board
Commission on Engineering and Technical Systems
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1988

EXECUTIVE SUMMARY

THE NATURE OF THE PROBLEM

Over the past two decades the number of nuclear reactors used for research and education on university campuses has declined from about 76 to 40. Moreover, while some universities continue to maintain and even upgrade their reactors, further reductions are expected. The reasons for this include competition for limited university funds, poor external funding prospects, lack of growth in the nuclear power industry, and, in some cases, prolonged hearings and litigation associated with licensing procedures. In effect a vicious circle has developed in which reduced support leads to lower faculty and student interest, which leads to under-utilization, which leads to lower motivation for continued support and so on.

It was a premise of this study that given the training, research, manpower development and other needs in the nuclear field, this trend should not be permitted to go too far. Policies that will limit closures and encourage modernization of a sustainable subset of existing reactors, sufficient in numbers and types to meet national and academic needs for research, education and service are clearly in the national interest.

To formulate such policies, the Committee addressed the following questions:

- What national interests (scientific, technical, medical and educational) are served by on-campus research reactors?
- What academic values derive from university reactors?
- Is federal financial support necessary or desirable to arrest current trends and assure the retention of an adequate population of university research reactors?
- What levels and types of federal support, if any, should be provided?
- What guidance can be offered to universities and to the federal government pursuant to reasonable and prudent licensing of university research reactors?

PRINCIPAL FINDINGS

Pursuant to the National Interest

The national interests served by university research reactors include:

- development of high-technology applications in fields such as materials sciences, fluid dynamics, and biomedical sciences, using reactors as sources of neutrons;
- research contributing to the future of nuclear power reactors, including the scientific basis for new concepts, for safeguards, and safety; and,
- education of personnel needed to operate, maintain and improve reactors and other facilities associated with national defense and nuclear power activities.

The Committee finds that the existing population of university research reactors, as a whole, does not adequately fulfill these national interests, particularly with respect to the use of neutrons in the development of high technology. Moreover, in several important research areas the U.S. is not currently on a par with Europe and Japan. Deficiencies at U.S. university research reactors, stemming in part from inadequate financial support, include inadequate peripheral research equipment such as spectrometers, cold sources, and radiographic equipment. The effects of these deficiencies would be reduced by better access for university-based researchers to major national facilities which are better equipped. But opportunities for such access are now inadequate.

The Committee is concerned that a failure to correct these deficiencies, coupled with a continuation of the trend in reactor closures, will serve to widen an existing gap of U.S. neutron science capabilities.

The Committee is also concerned that future national needs for nuclear engineers and scientists trained in the neutron sciences may not be met if the current negative trends continue.

However, selective reduction in the number of university research reactors will not of itself damage the national interest, provided that a healthy core of on-campus and off-campus research and educational reactor facilities is retained.

Pursuant to Academic Values

The Committee finds that on-campus research reactors contribute to academic values through research and education at the university, and through service to off-campus user constituencies:

Research: University research rectors are the focus of multi-disciplinary research with contributions to physics, chemistry, biology, medicine, epidemiology, environmental sciences, material sciences, fluid mechanics, geology, archaeology, paleontology, forensic sciences, and other fields in addition to nuclear engineering research and reactor physics. The three principal reactor research techniques are neutron activation analysis, neutron scattering, and neutron radiography. The latter two are largely confined to reactors of one megawatt and higher power. Research reactors in the United States constitute unique and essential research tools in several aspects: structural determinations of materials including superconductors and biological, ultrasensitive analysis for traces of elements, radiological display of physical phenomena, and introduction of radioisotopes for medical diagnostics and research (See Chapter 2).

Education: On-campus reactors have been a traditional focus of educational programs for nuclear engineers. In addition, on-campus reactors are increasingly used as laboratories by students in the non-nuclear fields listed above. Educational uses are made of even the smallest fractional watt on-campus reactors. Beneficiaries include graduate and undergraduate students, as well as nuclear power plant operators, secondary schools and the general public through outreach programs (See Chapter 3).

Service: University reactors, particularly those of one megawatt and larger, serve a range of off-campus constituencies: the medical community, industrial organizations, and government agencies. These clients use irradiated materials, materials analysis, trace element detection, and radiographic analysis of objects and processes. By providing such services, managers of university research reactors establish beneficial links to off-campus users, expose faculty and students to commercial applications of the nuclear sciences, and earn revenues to help support reactor programs (See Chapter 4).

The Committee finds that U.S. university research reactor facilities must be upgraded and provided with modern equipment if they are to meet their intended objectives and become world-class research and educational facilities. Needs include modern instrumentation, low temperature irradiation facilities, cold neutron capabilities, modern spectrometers, radiographic equipment, increase power and neutron flux, and other enhancements.

University administrators, in weighing the future of on-campus reactor programs take into account the following factors:

- academic benefits in terms of research, education, and service;
- costs of achieving these benefits including the costs of safety and safeguards, as well as dealing with legal actions and protests;
- the availability of resources from federal and other sources to defray these costs; and
- competition from other on-campus research facilities for limited financial and other resources.

The academic benefits associated with university research reactor programs are summarized above and are discussed in detail in Chapters 2, 3, and 4.

On-site reactors, clearly, enhance the educational and research missions of a university. Properly equipped and managed on-campus reactors offer unique advantages in terms of hands-on education and research experience in running small scale experiments which would not be practical at larger off-campus reactors. However, it cannot be concluded that every on-campus research reactor is essential to these missions. This depends on the particulars of the educational program, and on the nature of access to off-campus research reactors.

Pursuant to Procedures for Safety and Safeguards

The Committee observes that the safety and safeguard records of on-campus reactors have been excellent. Nevertheless, a growing concern for reactor safety, as well as the potential for sabotage and for theft of nuclear materials, has led the Nuclear Regulatory Commission to upgrade the requirements for the protection of all reactors from the largest 3500 Mw (thermal) electric power facilities, down to the smallest university reactor. The Committee does not take issue with the Commission with respect to these concerns. However, the Committee finds that some of the procedures of the Nuclear Regulatory Commission associated with improving safety and safeguards at university reactors can result in costs out of proportion to the improvements achieved. A particular concern is that relicensing procedures associated with reactor safety and safeguard upgrades can in some cases unnecessarily expose the universities to costly hearings and litigation. The Committee is also concerned that existing rules and procedures for the licensing of university research reactors have at times lent themselves to abuse by intervenor groups who use the opportunity to assert their larger political opposition to nuclear power and defense activities (See Chapter 6).

PRINCIPAL RECOMMENDATIONS

The federal government, in partnership with the universities and the national laboratories, should develop and implement a national research reactor strategy, the elements of which should include:

- development of university and national laboratory centers of excellence in specific areas of the neutron sciences and reactor technology for world-class research as well as for education;
- anticipation that as some university reactors are upgraded and a user's network is created (see below), others are likely to close;
- mechanisms to assure that such closures do not go so far as to damage the national interest related to research and educational capabilities in the nuclear sciences and engineering; and
- development and support of a reactor network to provide enhanced utilization and productivity of U.S. research reactors involving researchers from universities with and without on-campus reactors, and from the national laboratories.

To implement the above strategy:

- a single federal agency should be designated to administer programs in support of the national research reactor programs; and
- the federal government should create a standing advisory structure to advise on a continuing basis on all aspects of this program.

In pursuit of this strategy the Federal government should:

- adopt the goals of meeting U.S. research reactor needs, and regaining a position competitive with Europe and Japan in the neutron-based sciences;
- study, in detail, the approaches of other advanced countries to operating research reactor networks such as that of linking the major facility at Grenoble with smaller reactor research centers in Europe (see Chapter 5);
- establish and support such a network, adapted to U.S. needs;
- make up to $20 million available annually (as a preliminary estimate to be modified as improved data becomes available) to universities through the designated federal agency, specifically for operational support and facility upgrades of university research and educational reactors (see Chapter 7); and,
- create a peer review mechanism to assist the designated agency in making grants to universities.

The Nuclear Regulatory Commission should examine its current approach to the licensing and regulation of university research reactors in terms of the following issues:

- the small nuclear materials inventories and low power densities of university research reactors, which result in risk factors related to safety and safeguards considerably lower than commercial power reactors (see Chapter 6); and,
- avoiding unnecessary exposure of small university reactor operators to costly hearing and litigation procedures as a condition for licensing upgrades and improvements.

Finally, the Nuclear Regulatory Commission should consider grants of technical and financial assistance to help university reactor operators to comply with upgraded safety and safeguard requirements, including and continuing beyond the current program of assisting with the conversion to low-enriched fuels.

UNIVERSITY RESEARCH REACTORS AND TECHNOLOGICAL COMPETITIVENESS
1990

These examples are samplings taken from the activities at a few University Research Reactors during the last few years. No attempt was made to provide a comprehensive overview of similar contributions from all of the 35 operating URRs. Such a listing would be much longer. It is hoped that the examples given here will provide a good indication of the multi-faceted contributions of URRs to the country's technological competitiveness.

Further information can be obtained from the undersigned, who obtained and organized the material in this report.

Otto K. Harling
Massachusetts Institute of Technology
Member of TRTR

A. Francis DiMeglio
Rhode Island Atomic Energy Commission
Chairman of TRTR

Medicine

- Demonstration of radiation synovectomies, using URR produced radioisotopes, as a safer and cheaper alternative to surgery for rheumatoid arthritis.

- Development of the special neutron beams and other technology needed for neutron capture therapy of highly malignant cancers. This neutron capture therapy approach to treating deep-seated brain tumors holds the promise of curing these cancers, which account for about 10,000 premature deaths annually in the USA.

- Promising results have been obtained in clinical trials for over 100 liver cancer patients using a new radiopharmaceutical delivery system which targets liver tumors. The drug called TheraSphere® is based on glass microspheres which are made radioactive in a URR and which will localize in the tumor bed, providing a highly localized dose to the lesion.

- Pain palliation in cases of bone cancer has been demonstrated in initial clinical trials of 20 bone cancer patients, using a beta-ray emitting isotope chemically bonded to a phosphonate molecule (EDTMP). Other tumor targeting agents such as monoclonal antibodies are being developed in collaboration with radiopharmaceutical laboratories and medical institutions.

- Neutron activation analysis is used as a powerful prognostic and diagnostic tool in the study of diseases such as Alzheimer's.

- Large quantities of radioisotopes for routine commercial use and a wide variety of special-purpose radioisotopes for research and testing are produced for the medical industry.

- The technique of using stable but activable isotopes for medical studies, e.g. related to trace mineral nutrition studies has enabled rapid progress. These techniques are safer, do not involve radioactive isotopes in human subjects, and have a wide range of applicability.

Materials Science and Engineering

- A new high-performance magnetic material, Magnequench® for lightweight and inexpensive magnets has been developed with the assistance of neutron scattering studies at a URR. Performance is three times better than SmCo permanent magnets. This new material will help the US automotive and electronics industries remain competitive.

- The only gamma-ray scattering laboratory in the USA has been developed at a URR. Applications of this capability include determination of the perfection of crystals grown in gravitational force-free experiments during NASA shuttle flights.

- Neutron transmutation doping of silicon semiconductor crystals on a commercial scale was initiated and large quantities of silicon crystals are routinely processed for domestic and foreign semiconductor companies. This method of neutron doping produces superior quality semiconductors for power rectifiers and other devices used in industrial and in defense applications.

- Radiation-induced failures of great concern for space missions, for military applications, and in large semiconductor memories have all benefited directly from R&D at URRs. Such work has resulted in circuits and components which are much more tolerant of the radiation environments in which they must operate.

- Large-scale irradiation of topaz gem stones to enhance their commercial value is carried out.

- Neutron scattering facilities are used by industry to help develop and characterize new materials such as supermagnets and polymers, which have important commercial applications.

- Scientists at URRs have discovered that fast neutron irradiation can significantly improve the performance of the new high-temperature superconductors.

- Millipore filters for the semiconductor industry, medical diagnostics, environmental sampling, etc., are produced in large quantities using URR irradiations.

- Quality control of materials and processes is carried out to assist US industry in meeting quality control specifications, resulting in improved cost and product quality. Trace element determination using neutron activation analysis is one of the most important services provided to industry for these purposes.

- Radiation-resistant detector elements have been developed for large high-energy physics detectors, which should result in savings of about $20 million per year for the Superconducting Supercollider project.

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Manpower Development and Training

- URRs are an important training ground for university graduates who enter the commercial nuclear power industry. The most successful nuclear engineering academic programs are at universities which have URRs.

- URRs provide continuing education and training for many nuclear power plant workers.

- University reactors provide unique training for radiation health physicists, who are in short supply in hospitals; research laboratories; industry; in government positions, including the military services; and in the nuclear industry.

- Several of the larger URRs are the sources for a major fraction of our country's domestically-produced experts in neutron scattering. These experts are essential to the success of our national research reactor programs.

- In applications of nuclear technology such as neutron activation analysis and radiography the bulk of US education and training is centered at the URRs.

- Unique experience is obtained by students who assist in the design and construction phases of URRs, both new reactors and upgrades. Many of these students become leaders in the nuclear industry based in part upon their directly relevant experience at URRs.

Nuclear Power

- Technology has been developed that is expected to significantly reduce the occupational radiation exposure of nuclear plant workers. This will result in millions of dollars in cost savings each year, improving the public's perception of nuclear power generation and will make US nuclear power generation and plants more competitive relative to foreign competition.

- Sophisticated approaches to computer control and automation of nuclear reactors have been developed. This know-how is being transferred to special mission reactor projects such as space reactors and to the US nuclear power industry. Computer control leads to enhanced safety, efficiency, speed and reliability of reactor control. URR-based R&D is having a positive impact on the ability of the United States to maintain significant strength in the face of fierce international competition in these areas.

- Major R&D to improve structural material performance and useful lifetime is carried out in support of US light-water power reactors. The URR-based work is innovative and addresses important problems which have not been solved at the major national centers. Much of this work is supported by foreign companies, thus enhancing limited resources available in the USA. However, all results are also available to the US industry. An example of such work is a major research effort to understand irradiation assisted stress corrosion cracking using extensive in-reactor testing at a URR.

Automobile Industry

- Neutron radiography has been used to understand oil flow in shock absorbers and in engines during actual operation.
- Wear studies using radioactive tracers made in URRs help improve the performance of automobile components.
- Trace analysis using neutron activation has developed a clearer picture of catalytic converter degradation and environmental impact in automobile applications.

The Environment

- URRs have become one of the most powerful tools for studying the behavior of pollutants in the environment. Air and water pollution are being studied by neutron activation analysis to determine sources, transport, and deposition mechanisms.
- Cloud chemistry, which is directly related to acid rain, has been elucidated with studies using URRs.
- Sources of ground water pollution are traced to their origins and the actual levels of harmful components can be determined so that appropriate actions and responsibilities can be defined.

Geosciences and Planetary Science

- Most of the samples returned from the US moon expeditions were characterized at URRs.

- Geochemistry studies of the earth's crust and mantle depend heavily on neutron activation analysis using URRs. These studies improve our understanding of the subsurface behavior of the earth's crust and mantle and provide an important component of the models which are being developed to understand and predict major earth motion related to earthquakes.

RECENT IMPORTANT CONTRIBUTIONS OF UNIVERSITY RESEARCH REACTORS

February 1990

University research reactors are used in research, education, and service.

In research, University research reactors are the focus of multi-disciplinary research with contributions to physics, chemistry, biology, medicine, epidemiology, environmental sciences, material sciences, fluid mechanics, geology, archaeology, paleontology, forensic sciences, and other fields in addition to nuclear engineering research and reactor physics. The three principal reactor research techniques are neutron activation analysis, neutron scattering, and neutron radiography. The latter two are largely confined to reactors of one megawatt and higher power. Research reactors in the United States constitute unique and essential research tools in several areas: microstructural determinations of materials including superconductors and biological, ultrasensitive analysis for traces of elements, radio-logical display of physical phenomena, and introduction of radioisotopes for medical diagnostics, therapy, and research.

In education, on-campus reactors have been a traditional focus of educational programs for nuclear engineers. In addition, on-campus reactors are increasingly used as laboratories by students in the non-nuclear fields listed above. Educational uses are made of even the smallest, fractional watt, on-campus reactors. Beneficiaries include graduate and undergraduate students, as well as nuclear power plant operators, secondary schools and the general public through outreach programs.

In service, University reactors, particularly those of one megawatt and larger, serve a range of off-campus constituencies: the medical community, industrial organizations, and government agencies. These clients are irradiated materials, materials analysis, trace element detection, and radiographic analysis of objects and processes. By providing such services, managers of university research reactors establish beneficial links to off-campus users, expose faculty and students to commercial applications of the nuclear sciences, and earn revenues to help support reactor programs.

Recent important contributions have been made in all of these areas. A few examples follow.

<u>The use of neutron activation analysis has led to:</u>

- The development of a new general theory of mass extinction in the Phanerozoic era, as well as an understanding of planetary development from a study of lunar and other cosmolcgical samples.

- A better understanding and predictive ability for earthquakes and eruptions in the western United States.

- The discovery that arctic haze is pollution aerosol from mid-latitudes, Eurasia, and not from North America or the Far East.

- A better understanding of trade routes and exchange of goods in pre-Hispanic Mexico and among prehistoric peoples.

- The determination of correlations between dietary trace element nutrients and human disease such as breast, prostate, and cervical cancer and adult onset diabetes.

In the areas of nuclear and condensed matter physics:

- The design, construction and use of a unique small-angle polarized neutron spectrometer, the only one of its kind in the United States.

- The development of two-crystal method of measuring total slow neutron cross sections.

- First measurement of depolarization by a flux lattice in an epitaxially grown single crystal of high critical temperature, YBaCuO superconductor.

- First characterization of HgI2, a potentially important electronic material grown in the microgravity experiments of shuttle mission Space Lab III.

- The development of a new technique for characterization of defects in semiconductor, deep level transient spectroscopy (DLTS).

- The development for the automobile industry of a powerful but lightweight permanent magnet which can be made from inexpensive materials and will help the United States industry remain competitive.

In the area of medicine:

- Development and use of epithermal neutron beams for treatment by neutron capture therapy of deep seated brain cancers.

- Boron neutron capture therapy studies using in vitro cell media and boronated mono and polyclonal antibodies.

- Research, development, and production of radiopharmaceuticals for diagnosis and innovative treatment of cancers.

- Production of physiological short-lived isotopes for researchers for in vitro study of hypertension, cystic fibriosis, cancers, and other diseases.

In the area of engineering:

- Determination of optimum water chemistry parameters to minimize radiation exposure to nuclear power plant workers.

- In-Situ testing of radiation damage effects to electronic components of reactor power conditioning circuits.

- The determination of the useful service lifetime of nuclear power plant structural

materials.

- Development of non-linear digital feedback control of power reactors with experiments using a university research reactor.

Prepared by

A. Francis DiMeglio, Chairman of TRTR
Otto K. Harling, Chairman, TRTR Sub-committee on URR Funding

Mrs. LLOYD. I appreciate your being here, Dr. Voth.
Dr. Jones?

STATEMENT OF DR. BARCLAY G. JONES, PROFESSOR AND HEAD, DEPARTMENT OF NUCLEAR ENGINEERING, UNIVERSITY OF ILLINOIS

Dr. JONES. Thank you, Madame Chairwoman. As Dr. Voth pointed out, I am here to represent the NEDHO, Nuclear Engineering Department Heads Organization, and to testify on their behalf and in conjunction with TRTR. As you have heard earlier, we have proposed the joint budget for fiscal year 1992 of $17 million.

NEDHO is made up, by its title, of nuclear engineering department heads. It is represented in 27 states of the country. Many of these institutions have research reactors.

Since being here with you last year, I referred in those remarks to a study that was underway and was about to be published. It was published in June, or released in June, and those findings bear out the fact that the nuclear engineering community is underfunded. It is rapidly falling behind in terms of producing the number of people needed by demand and a variety of other statistical type of information that supports those two items.

I come to you today with an even more urgent plea, I believe, and much in mind with the type of questions that you were directing to Dr. Decker earlier. That if we are to maintain the nuclear engineering option in terms of power, in terms of research and, in particular, in terms of nuclear engineering education, we need to be doing more than we are at the present time.

We are still seeing the drop-off in the number of programs—approximately two per year. This is now getting to the core of where the number is dropping to a level at which we no longer will have the type of broad representation we have currently. We no longer will be able to respond to an increasing demand that is projected with several items that are on the current agenda—one of those being waste clean-up, which is already here and is making a fairly strong demand for a number of graduates from our programs at this time. It is projected over the next decade or so, there will be 200 new jobs in that area created annually. If those are at the BS level, that will take virtually all of the U.S. graduates that don't go on to graduate school and go into industry. That leaves none for the power industry. It leaves few for the other auxiliary industries that are currently also hiring nuclear engineers.

I think it is appropriate to recognize the leadership that your committee has given over the past four years in supporting through energy research several of the initiatives, primarily the research initiative, which has provided opportunities for training people at the graduate level, particularly at the PhD level in fundamental research in nuclear engineering.

I have included a table in the material this time that essentially picks up on the table we submitted last year, and shows again the overwhelming subscription to the funding made available through your program. For approximately $1 million worth of new starts and a continuation of some $4 million, there were 125 proposals submitted totaling $38 million. Those reviews have just been com-

pleted, but again, the "must fund" category came out in the 20-30 percent range. They will probably be able to fund, at most, ten percent of those proposals. I think this is really at the core of maintaining research programs in the various departments of nuclear engineering.

In addition to that, we have proposed that the graduate fellowship and trainee programs that Dr. Decker spoke of earlier, be increased. The amounts of money that are in those now provide what we feel is not enough support to attract the available domestic qualified PhD students into continuing education. They are just not coming in unless you can attract them with those or with research funding. So we are suggesting that that be increased beyond the type of level that is currently underway.

We also see that the minority programs are particularly important. We see minority programs as important because there will be more minority students available. Now whether they are available through the typically black colleges or not is a question. I think that, as Dr. Decker pointed out, the ability to track and train and attract qualified people to teach in those institutions at the research level, and therefore, produce the advanced degree people, is limited at the present time.

There are opportunities for minorities to enter through the nonblack colleges. We think that emphases can be properly put in those areas to attract and retain the disadvantaged and the minority population in those areas. Indeed, if we look at the demographics, that is where the majority of the increase in the science population is going to have to come from.

We also have noted, the same as you had, that if we expend a large amount of effort attracting K through 12—and I am not sure that one year will do that because you only graduate grade 12 each year—that is a long process. I am particularly concerned that our graduate programs, and particularly in nuclear engineering, are not going to be in a position to be able to handle the increased level that this is expected to generate.

We are now getting down to where the elasticity in our programs is not capable of responding to significant increases in student population. The undergraduate level is easier, but their laboratories and so on require new space or additional space, additional equipment. When you go to the graduate level, the number of research program dollars and the number of faculty is linearly related to the number of graduate students. So if you increase that, you must increase the faculty.

You asked us to respond to a couple of needs, but let me go back to that other item. I think that it is probably folly to expect that you can spend a couple of years on K through 12, and then switch your emphasis to the higher education programs and expect to have taken care of both issues. Unfortunately, I am reading into the suggested approach for this that, that could very well be the approach that is being suggested, and I am concerned about that. I would expect that this would be a concern of other people.

We are encouraged to note that nuclear energy did include in their budget $2.5 million for nuclear engineering in fiscal year 1992. It has been designated that this was for specific purposes, for fellowship and scholarship programs, to encourage students to

pursue careers in nuclear engineering, and for improvements in the university engineering departments and curriculum—a nice broad statement, and, therefore, presumably a lot of flexibility.

I am happy to indicate that there is an initiative afoot, that might very well leverage money from the industrial community on an equal basis. If that occurs, this will provide a jump start, if you will, to some of the nuclear engineering programs. We expect to know the response to and by the department and by the industry, within a matter of weeks on that. So it is a very encouraging turn of events, I believe. Everybody needs graduates and everybody is getting interested.

You also asked us to comment, and Dr. Voth did, in relationship to where the funding is placed. We have needs for a variety of funding. We don't have strong feelings as to which it comes through, which of the offices in the Department of Energy. But if it is handled on the basis that the funding that you have provided has been handled, it is being handled very well. So we are reluctant to suggest that it be changed.

You also asked who is hiring the nuclear engineering graduates. Well, we have a snapshot out of this report by the National Academy, which, by the way, the Department of Energy was a cosponsor of. That was for the year 1989. Let me just indicate there, in the table included on page 6, that the Federal Government is by far the largest individual user of graduates. Therefore, it is not unrealistic to think that they maybe should bear a certain amount of responsibility for education in these areas.

I would just like to close by indicating that I believe the information available to us now, from that particular study and from the reactor study earlier in 1988, is sufficient evidence to indicate that there is a strong need to support both the university reactor programs and the nuclear engineering programs.

I appreciate very much the opportunity to bring a message to you.

[The prepared statement of Dr. Jones follows:]

Testimony

Presented to the

COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

SUBCOMMITTEE ON ENERGY RESEARCH AND

DEVELOPMENT

by

BARCLAY G. JONES

Professor and Head

Department of Nuclear Engineering

University of Illinois

at Urbana-Champaign

and

Past - Chairman

Nuclear Engineering Department

Heads Organization

On behalf of the

Nuclear Engineering Department

Heads Organization

March 19, 1991

Madame Chairman, Members of the Committee:

I am Barclay G. Jones, Professor and Head of the Department of Nuclear Engineering at the University of Illinois and immediate past Chairman of the Nuclear Engineering Department Heads Organization (NEDHO). I am testifying today on behalf of NEDHO, and in conjunction with the National Organization of Test, Research and Training Reactors (TRTR), on the policy implications of the Department of Energy's Fiscal Year 1992 budget request relating to Nuclear Engineering Research and Education and to University Research Reactor programs. We welcome the opportunity again to testify in support of these two programs, which we feel are vital to the long term interests of the United States. Together with TRTR, we have outlined a comprehensive program, to be fully implemented over a three year period, for which we request your consideration and support for $17 million for FY 1992, the initial year of this program. This includes $11 million for Nuclear Engineering Research and Education programs and $6 million for University Research Reactor programs.

Appended to my testimony are additional supportive documents which, with your permission, I request be entered into the record with my oral testimony.

NEDHO is composed of the academic leaders in nuclear engineering and applied nuclear science at colleges and universities in 27 states. Many of these institutions have research reactors which are directly associated with their educational programs and are part of TRTR.

Since the time we jointly testified last year, the panel formed by the National Research Council and National Academy of Sciences has completed its investigation and published its findings in a report entitled, "U.S. Nuclear Engineering Education: Status and Prospects" via National Academy Press, 1990. A review of this report is included with this testimony as Attachment 1, and a copy of the Executive Summary is included as Attachment 2. These two documents clearly define the important role of the universities and the need for increased federal support for nuclear engineering education.

Universities involved in nuclear engineering education and research appreciate the vision and leadership of the Subcommittee on Energy Research and Development which has resulted in funding of $5 million in FY88, $6 million in FY89, $7 million in FY90 and $6 million in FY91 for support of nuclear engineering students and research, and for university research reactor support. These appropriations have been ably administered by the Office of

University and Science Education in DOE Office of Energy Research and have had an extraordinarily positive and invigorating impact. In particular the appropriations in support of University Nuclear Engineering Programs have resulted in additional DOE Nuclear Engineering and Health Physics Fellowships, have increased the support at minority institutions, and have initiated an extremely effective multi-year research projects program in basic nuclear engineering areas.

The Nuclear Engineering Research Program, managed by the Idaho National Engineering Laboratory (INEL), has allowed faculty and students to conduct research on innovative new nuclear engineering ideas, through peer reviewed and competitively awarded projects. In response to this year's Program Notice, which unfortunately has had to be limited to $1 million for new starts, 125 proposals with a face value of $38.6 million have been received by INEL, indicating the abundance of new research ideas and the mismatch between need and available support. Table 1 shows the history of the program since its inception. This clearly shows the disparity between need and available support that has existed throughout the program's history.

The research program is extremely important because it provides previously unavailable opportunities for faculty (especially young faculty) to explore long-term, innovative initiatives which could have a great impact in applied nuclear science and technology. The current DOE program permits faculty to investigate new research ideas covering the entire spectrum of nuclear engineering activities. The projects can be performed over 2 to 3 years which allows doctoral students the time necessary to complete their Ph.D. research and dissertation as part of the project. We very much appreciate the Committee's actions which have led to the establishment of this program. From the continued demonstration of need through proposal submissions and their high quality as indicated by peer reviewers, we believe that this component of the program deserves to be increased to the level recommended in the National Academy of Sciences study. This component will require $6.5 million in FY92 and is proposed to reach an equilibrium of $13 million in FY94. These, and other requested funding recommendations through FY94, are shown in Table 2.

Other integral parts of the proposed program are the graduate fellowship and traineeship components, including support for minority institutions. These four year student stipends enable U.S. citizens, who might not otherwise

purse graduate degrees, to embark on Ph.D. programs. The importance of this program cannot be overemphasized, since, at the present time the supply of B.S. nuclear engineers graduates is now less than their demand, the top calibre U.S. students are receiving multiple offers at extremely attractive salaries. While these graduates will undoubtedly make valuable contributions in their professional positions, it is absolutely critical to attract the most capable students into advanced degree programs if we are to have the research capability in this country to compete successfully in the burgeoning areas of high technology. Although, the number of Ph.D.'s awarded in nuclear engineering and health physics has not changed significantly over the past ten years from near 110, the mix has changed from 70 percent to less than 60 percent of the degrees going to U.S. citizens. This number of U.S. citizen graduates does not begin to approach even the new personnel needs of the federal laboratories, not to mention their replacement needs. The situation is also exacerbated by the fact that Ph.D. nuclear engineers, with their insight into the engineering aspects of nuclear forces and nuclear processes, are vigorously recruited for positions that are not commonly thought to be labeled "nuclear engineering". These positions are in areas such as materials science, medical applications, accelerator technology, space power applications, and other areas which far transcend the field of light water nuclear power plants and advanced power systems such as LMR and HTGR. Meanwhile, the continuing need for qualified personnel in the commercial nuclear industry places even greater pressures on the demand for nuclear engineers. It is for these reasons that the DOE Nuclear Engineering and Health Physics Fellowships are especially important, because these allow the talented U.S. students to have assured financial support which will take them through to the completion of the Ph.D. degree. Without this type of commitment, many very capable B.S. graduates opt directly for industry careers which, though important, will preclude their participation in the long-term research endeavors and technology development of the U.S.

To respond to this need we have proposed adding in each of the next four years 10 new, fully-funded DOE Nuclear Engineering and Health Physics Fellowships. This would approximately double the existing DOE Fellowship program in these two areas, which is being successfully administered through Oak Ridge Associated Universities.

The two other areas in which we believe the needs justify expansion of nuclear engineering educational programs are for minority institutions and students and to reinstitute the DOE Traineeship Program. The number of minority students in engineering is disproportionately low, and nuclear engineering is no exception. Therefore, we suggest that $1 million per year could be used to improve substantially minority representation within nuclear engineering. In order to attract and directly introduce advanced degree students to nuclear engineering activities in the DOE national laboratories, we believe that an internship can be used effectively. We suggest that this can be introduced through a DOE Traineeship Program, and we have again proposed introducing this in FY92 at a constant yearly level of $1 million, which appears within the budget line in which the Office of Nuclear Energy funding is indicated.

In the proposed budget, the nuclear engineering components (i.e. NEDHO related) are shown in the upper half of Table 2. The budget is based on three years, showing a gradual phase-in of the research programs and reaching a nominal equilibrium level in FY94. We believe these are realistic and conservative levels of support necessary to retain viable nuclear engineering academic programs and to meet the immediate demands for nuclear engineers. However, it is unclear when the resumption of new nuclear power plant orders occurs, whether the existing programs will be capable of expanding enrollments significantly without increases in faculty and in teaching laboratories and space. Thus, it is critically important to retain strong nuclear engineering academic programs which can not only meet current manpower needs, but respond to anticipated and predicted increased needs.

The above recommendations are based on demonstrated and essential needs of the Nuclear Engineering Education programs, and on the closely allied University Research Reactor programs. These serve vital roles in assuring the nation's energy supply, providing graduates for key roles in national security, and undertaking leading edge research critical to our competitiveness in high technology areas in the international marketplace. With the recent significant thrust of the Department of Energy in both primary and secondary education areas, it would be tragic if we were to successfully increase the supply of high school students desiring nuclear engineering, only to be unable to accommodate them in undergraduate and graduate programs. We believe that the current decreasing trend of both number and size of nuclear

engineering degree programs must be addressed. Unfortunately, the Department of Energy's proposed budgets over the past five years have conspicuously omitted funding for programs which we have proposed to your Committee, and for which this Sucommittee has subsequently appropriated funds. Further, the two national studies, on Nuclear Engineering Education (1990) and on University Research Reactors (1988) which were partly supported by DOE, have clearly identified urgent needs and specifically recommended significant levels of new funding necessary to address these needs. We believe that it is imperative that the Department of Energy be responsive to the results of these studies and change its recent budgeting policy to include, in its future budgets, funding to address these needs. We note, and very much appreciate, the line item in the Office of Nuclear Energy DOE FY92 budget of $2.5 million, which is designated for fellowship and scholarship programs to encourage students to pursue careers in nuclear engineering; and for improvements in university nuclear engineering departments and curricula. Although, this funding does not address either the Nuclear Engineering Research program or the University Research Reactor programs, it is expected to have significant impact on nuclear engineering students and aon nuclear engineering departmental support services.

In response to your Subcommittee's interest in a comprehensive program actively including Nuclear Engineering Research and Education and University Research Reactors, NEDHO and TRTR collectively support such a program. Indeed, our combined budget (Table 2) and our coordination of programs over the past three years attest to our support of this approach.

The recent study of U.S. Nuclear Engineering Education (1990) provides a comprehensive review of current and projected manpower needs and of historical hiring patterns of graduates with nuclear engineering degrees. As shown in the report, the percentage of graduates entering the U.S. workforce in 1989 was:

	Degree		
Placement	BS	MS	Ph.D.
Nuclear utility	23	30	9
Other industrial	26	20	17
Academic	4	4	26
Federal Government*	40	35	41
Other	7	11	7

*Includes DOE contractors and military

These data show that the federal government is the largest employer at all degree levels. With the a[illegible] demand over the past year in federal site clean-up programs, the federal government percentage has increased. Therefore, it appears approporiate that federally supported programs be utilized to help with nuclear engineering manpower supply.

From these observations we believe it is apparent that Nuclear Engineering Education and University Research Reactor programs merit consideration and support of your Subcommittee. We encourage you to endorse the phased program which we have proposed and to urge the Department of Energy to adopt it.

Table 1.

DOE-OER Nuclear Engineering Research

Funding Summary

	FY 1988	FY 1989	FY 1990	FY 1991
PROPOSALS:				
# Received	163	155	93	125
Funding Requested	$47,630,000	$45,600,000	$32,150,000	$38,651,000
PANEL REVIEW:				
# Recommended	39	45	34	
Funding Required	$14,350,000	$13,630,000	$10,120,000	
GRANTS:				
# Approved	18	18	11	
Funding Requested (3 year total)	$6,205,000	$6,120,000	$2,570,600	
GRANTS:				
# Issued	17	32	43	
Actual Funding (annual total)	$2,199,643	$3,858,742	$4,704,949	

Table 2.

PROPOSED BUDGET
U. S. Department of Energy
Office of Energy Research
Office of University Programs
Nuclear Engineering and University Research Reactor Programs

FY91-93

	FY91 Requested	Funded	FY92 Requested	FY93 Requested	FY94 Requested
Ongoing Research Projects	4.0	2.7	2.5	5.2	8.0
New Research Projects	4.0	1.2	4.0	4.0	5.0
DOE Nuclear Engineering and Health Physics, PHD Fellowships (10 new, fully funded for four years)	1.0	0.4	1.0	1.0	1.0
Minority Institutions Program	1.0	0.2	1.0	1.0	1.0
DOE Traineeship Program	1.0	0	2.5(NE)	2.5(NE)	2.5(NE)
Subtotal (NEDHO)	(11.0)	(4.5)	(11.0)	(13.7)	(17.5)
Expanded Reactor Sharing Program	1.0	0.5	1.0	2.0	3.0
Reactor Equipment Modernization	3.0	1.0	3.0	5.0	5.0
Reactor Upgrade	1.0	0.0	1.0	3.0	7.0
Reactor-based Research Programs and Operations	1.0	0.0	1.0	4.0	8.0
Subtotal (TRTR)	(6.0)	(1.5)	(6.0)	(15.0)	(23.0)
TOTAL	17.0	6.0	17.0	28.7	40.5

Attachment 1

Review of the National Academy of Sciences

Study title
"U.S. Nuclear Engineering Education: Status and Prospects"

(appeared in the January 1991, issue of Nuclear News)

education

REPORT

A coming shortage of nuclear engineers

Although supply of and demand for nuclear engineers at present is relatively in balance, the near-term prognosis is that a shortage of nuclear engineers could occur as soon as 1995, if recent downward trends in nuclear engineering enrollments at United States universities continue. Undergraduate enrollments numbered about 1150 in 1978, says the report; by 1988, that number was around 650. Graduate enrollments have seen a similar decline, but PhD numbers have remained quite steady, at about 600. The number of universities offering undergraduate nuclear engineering programs also has fallen, from 80 in 1975 to 57 in 1989. University research reactors numbered 76 some 20 years ago; today, only 27 remain, 21 of these located at universities with nuclear engineering degree programs or options in nuclear engineering.

These are among the findings of a comprehensive study conducted by the Committee on Nuclear Engineering Education, under the auspices of the National Research Council's Energy Engineering Board. Based on their mutual concern over declining enrollments, the American Nuclear Society, the Institute of Nuclear Power Operations, the Nuclear Engineering Department Heads Organization, and the U.S. Department of Energy were among those organizations that participated in the study, the results of which appear in a recently published report titled *U.S. Nuclear Engineering Education: Status and Prospects*. Gregory R. Choppin, of Florida State University, chaired the committee.

The committee was assigned the following tasks:

- To characterize the current status of nuclear engineering education in the United States.
- To estimate the supply and demand for undergraduate and graduate nuclear engineers in the United States over the near to mid-term.
- To address the spectrum of material that the nuclear engineering curriculum should cover and how it should relate to allied disciplines.
- To recommend appropriate actions to ensure that the nation's needs for competent nuclear engineers, as represented at both graduate and undergraduate levels, are satisfied over the near and mid-term.

A significant factor that may contribute to the problem of meeting demand requirements for nuclear engineers is lack of an adequate supply of faculty to teach nuclear engineering.

Employment outlook

The committee examined the job market for nuclear engineers, providing low-growth, best-estimate, and high-growth scenarios for civilian employment of nuclear engineers over the next 20 years (see Fig. 1). The report estimates that increased demand for nuclear engineers in the United States over the next five years will be chiefly due to expansion of DOE program initiatives in such areas as environmental remediation, nuclear waste disposal, new production reactors, defense-related and nuclear energy research and development programs, and augmentation of its nuclear engineering staff. Beyond the year 2000, demand is anticipated to be tied to the number of nuclear power plants in service, the possibility of a resurgence in nuclear power plant orders, the number of plants under construction, and plants undergoing life extension work.

The committee's best-estimate figures project 50 percent and 25 percent increases in employment demand for 1995 and 2000, respectively, and, if new plants are ordered as anticipated, a doubling or tripling of demand after 2000.

Who will teach?

A significant factor that may contribute to the problem of meeting demand requirements for nuclear engineers is lack of an adequate supply of faculty to teach nuclear engineering, in addition to the decline in the number of universities

offering nuclear engineering programs. Among concerns noted are that nuclear engineering faculty tend to be 8–10 years older, on average, than faculty in other engineering disciplines; only about 17 percent of present faculty are 40 years of age or less, and have less than five years of teaching experience. A major contributing factor to the aging faculty problem is the general downward trend in student enrollments and degrees awarded in nuclear engineering since 1978 (although the latest Manpower Assessment Brief issued by the DOE indicated a slight increase in nuclear engineering enrollments for 1989—see *NN*, Nov. 1990, p. 110), which has limited the addition of junior faculty members. It is also anticipated that industry will be competing for the services of nuclear engineers, drawing nuclear engineering instructor prospects away from academia. In addition, although no specific problems were identified by the committee, the age of the faculty raised concerns about the degree of innovation and the reference to contemporary issues in present coursework.

The difficulties of replacing faculty members as they retire or resign were noted in the report, and, if the demand for nuclear engineers increases as projected, faculty size will have to be at least maintained, or, more likely, increased. With a lead time of 8–10 years to bring new faculty on line (i.e., an entry-level student going through bachelor's, master's, and PhD levels to then qualify as a nuclear engineering faculty member), the committee recommended that innovative programs, such as partial or phased retirement of older faculty, be instituted in order to retain access to their special capabilities and skills and, at the same time, allow for the addition of junior faculty in a timely, effective manner. The committee noted that failure to introduce young faculty to nuclear engineering programs also will limit research development, and could seriously hamper program continuity.

At the undergraduate level, the number one problem noted by survey respondents was the need for improved oral and written communication skills.

Curriculum status

The committee viewed the overall content of nuclear engineering curricula as basically satisfactory. From a survey of institutions and firms that hire undergraduate and graduate nuclear engineers, the committee extracted information on areas that need to be strengthened in nuclear engineering programs, as well as learned what skills potential employers deemed desirable or necessary in a prospective employee.

At the undergraduate level, the number one problem noted by survey respondents was the need for improved oral and written communication skills. "This problem may owe in some degree to the growth in the number of graduate students for whom English is not a first language," says the report. "Such a response relates to engineers in general—in fact, to most professionals—and seems to indicate the need to enhance communication skills in this information age; it may also reflect the importance and widespread use of engineering teams in which communication is important. Courses should be designed for students to exercise and develop communication skills."

Respondents also viewed strong skills in reactor physics, reactor operations, health effects of nuclear radiation, reactor safety, and other areas related to commercial power reactor operation as necessary. The committee concluded that the current curriculum is generally successful in providing this training.

Although some positions could be filled by engineers trained in other disciplines, nuclear engineers are preferred for positions or tasks requiring an understanding of system behavior, such as serving as shift technical advisor at a power plant or performance of safety systems analyses. The survey results point out the need to emphasize systems education in the nuclear engineering curriculum. Part of the problem in this area once again has to do with the faculty situation. With nuclear engineering faculty aging and class sizes decreasing, universities often do not replace faculty members who retire or resign. When they are replaced, new faculty come from graduate programs that place less emphasis on commercial power reactor systems. Continuation of this trend could weaken teaching in reactor technology, to the detriment of the education of undergraduate nuclear engineers needed for the future.

Looking at graduate curricula, the report notes that research is closely tied to graduate education. "In our survey of skills needed by graduate engineers," reported the committee, "the ability to conduct independent research was the most widely needed skill identified." Also, as with undergraduate nuclear engineers, potential employers stressed the importance of strong communication skills and understanding of nuclear energy systems.

The study points out that research, and, subsequently, funding, related to

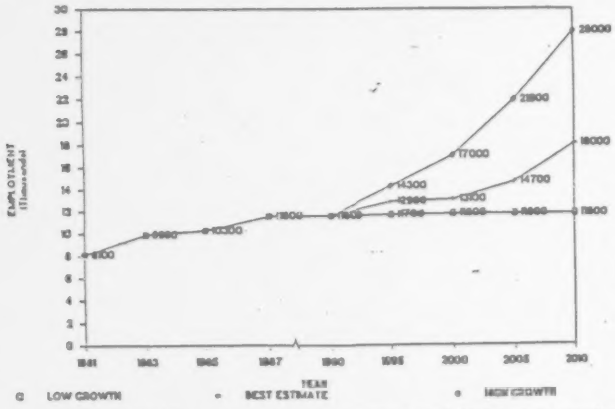

Fig. 1. Projected total civilian employment of nuclear engineers, 1990–2010, for three scenarios (estimated to the nearest hundred)

". . . the national nuclear engineering research program has moved so sharply away from nuclear power directions that some balance of activities seems to be in order."

commercial power reactors has substantially declined, partly because of the broadening of the research base to encompass nonpower areas. The committee recommends that reactor research funding be increased, although the increases need not be large. It was agreed that the diversification of nuclear research is good, but that, "On the other hand, the national nuclear engineering research program has moved so sharply away from nuclear power directions that some balance of activities seems to be in order." The committee's suggestion is that reactor-related research funding represent 25–30 percent of total nuclear research funds, instead of the current 15 percent. That is, the DOE's Office of Energy Research should increase its current $4 million appropriated for reactor-related research to some $11 million, which would amount to about 27 percent of nuclear research funding. This additional funding, according to the report, would support some 250 additional graduate students, whom the present programs could easily absorb, thereby strengthening nuclear engineering education.

So many jobs, so few engineers

As indicated earlier, with degree trends headed generally downward and anticipated job opportunities on the rise, there is concern that there will not be enough nuclear engineers to fulfill demand through the end of the century, and into the early part of the 2000s. As displayed in Fig. 2, shortfalls are almost certain unless significant changes are made. The figure shows actual and projected graduates available for employment and demand, and estimates of additional students that could be educated each year without additional faculty or facilities. The report explains that this analysis assumes no further decline in the supply of new graduates, and while the most recent enrollment and degree data appear to support the view that the decline has largely ended, it is still too early to know for certain that this is true. Also, although some schools report enrollment increases and healthy programs, several others are discussing phasing out their programs.

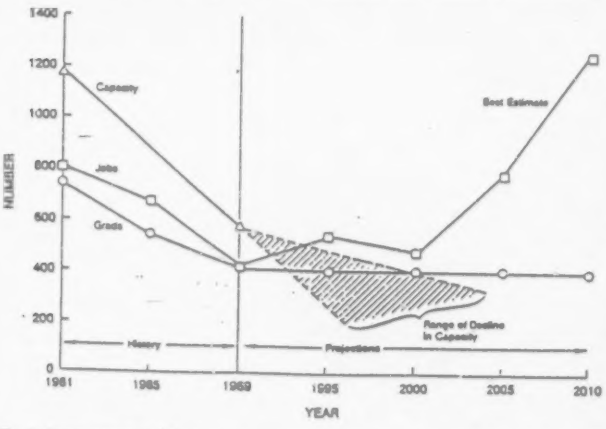

Fig. 2. Supply and demand projections for new graduate nuclear engineers in the U.S. civilian labor force

Other findings of the committee concerning supply and demand are the following:

- Although the number of degrees awarded in quantitative fields (engineering, mathematics, the physical sciences, and computer and information sciences) between 1978 and 1988 increased at all degree levels, the number awarded annually in nuclear engineering decreased at the BS and MS levels and remained steady at the PhD level. For U.S. residents, nuclear engineering degrees decreased at all levels.
- The potential for increased demand is greater than the potential for increased supply, chiefly because student populations are decreasing.
- Between 1977 and 1987, the absolute numbers and shares of total engineering and nuclear engineering degrees earned by women increased, and there has been a slight but positive shift toward women choosing quantitative fields for study.
- The requirement for security clearances in many nuclear engineering jobs limits employers' ability to draw from an increasingly international supply of professional labor. The supply concern is magnified by the decline in the percentage and numbers of MS and PhD degrees in nuclear engineering being awarded to U.S. citizens.
- Quantitative degrees earned by minorities increased between 1977 and 1987. Data also show shifts in minorities' field choices toward quantitative fields, which presents an opportunity to attract more minority candidates to nuclear engineering. This is seen as a necessary strategy, considering the increasing proportion of minorities in college populations.
- It is not likely that many students can be drawn from other quantitative fields to fill nuclear engineering positions, since the demand in other areas is also expected to rise.

Additional recommendations

"The responsibility for nuclear engineering education is shared by the federal government, private industry, and the academic community," states the report. The committee noted a number of recommendations to decision-makers in each of these sectors, and expressed its opinion that since the expected near-term shortage of nuclear engineers will be a result of expanded government programs, the DOE has added responsibility for near-term solutions.

The committee noted that the DOE could directly influence the number of students and the direction of research through increased funding for traineeship and fellowship programs; making additional research funds available to support work in the area of nuclear power re-

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actors, enhancing programs to attract women and minorities, and considering providing funds for nuclear engineering participation in minority-oriented science and technology initiatives, particularly those being established by the National Science Foundation; assessing support of access of all university nuclear engineering departments to research reactors; and updating the nuclear engineering personnel data base so that it accurately reflects supply and demand. "Adequate data bases will also be important to assess current and future issues," declared the committee. "This study was slowed by the inadequacy, incompleteness, and incompatibility of existing data bases on the employment of nuclear engineers."

Longer term increases will likely be the result of a resurgence in the use of nuclear power, and so industry's responsibilities lie with helping to ensure the needed supply of properly trained people for the longer term. Among actions the committee recommended were that electric utilities and the supporting industry increase participation in and support of U.S. nuclear engineering education through cooperative student programs, research sponsorship, scholarships and fellowships, seminar sponsorship, and establishment and support of academic chairs. Also, the committee endorsed continued work with ANS and other professional engineering societies in support of their programs in nuclear engineering education advocacy.

The report contains many details about and in addition to the areas discussed. Included are numerous graphs and tables, and appendixes encompassing the committee's statement of task, biographical sketches of committee members, study chronology and activities, acknowledgment of data sources, the assumptions and forecasting model for estimating projected demand and employment, additional data on nuclear engineering supply trends and curriculum, and the questionnaire sent to nuclear engineering departments to obtain necessary data for the study.

Copies of *U.S. Nuclear Engineering Education: Status and Prospects* are available for $15 from the National Academy Press, 2101 Constitution Ave., N.W., Washington, D.C. 20418; phone 202/334-3313.—*Betsy Tompkins*

COOPERATIVE EFFORT

U.Va. and Cybermotion join in robotics research

A cooperative effort has been undertaken between Cybermotion Inc., of Roanoke, Va., and the University of Virginia to develop new uses for robotic vehicles. Cybermotion has delivered one of its robotic vehicles—Navmaster—to U.Va. to be used in a one-year study led

Attachment 2

U.S. Nuclear Engineering Education:

Status and Prospects

EXECUTIVE SUMMARY

BACKGROUND

Nuclear engineering may be broadly defined as the discipline concerned with the utilization of nuclear processes and nuclear forces in engineering. The first formal U.S. academic programs in nuclear engineering were established in the mid-1950s. These early programs were at the graduate level, primarily emphasizing nuclear physics, reactor physics, and neutron transport analysis. With the emergence of the commercial nuclear power industry, undergraduate programs were established in the early 1960s.

The initial growth of these programs was rapid: 80 nuclear engineering departments and programs had been established by 1975, along with 63 programs in health physics. This rapid growth created faculties composed of those who themselves had been educated--in the absence of nuclear engineering departments--in disciplines such as nuclear physics, radiochemistry, and electrical engineering.

Nuclear science and engineering were glamour fields in the 1950s and 1960s, attracting students who were, on average, well above the norm for science and engineering students. This trend was promoted by the strong growth in the nuclear power industry, a relatively large number of fellowships provided by the U.S. Atomic Energy Commission (AEC), and the ample support of university research programs and nuclear reactors for research and education. The AEC awarded 129 graduate fellowships in nuclear engineering in 1963, and 76 university research reactors were in operation by 1970. Such numbers reflected a national commitment to the development of civilian nuclear power as expressed in the "Atoms for Peace" policy of the Eisenhower administration.

During the last two decades, the national commitment to nuclear applications has weakened considerably. By 1987 only 27 university reactors were operating, and by 1989 the number of nuclear engineering degree programs declined to 39, and nuclear engineering concentrations to 18. Of these, 20

programs had less than 20 students each; 50 percent of the students are in 14 programs. This decline has inhibited the addition of young faculty, who are needed for the long-term quality and vigor of any academic discipline. Over one third of the nuclear engineering faculty are 55 years of age or older, while only 16 percent are 40 or younger. This is approximately 10 years greater than the national average for engineering faculty. In the last decade, there has also been a 30- to 35-percent decrease in the number of undergraduate and graduate students majoring in nuclear engineering. Federal fellowships declined to as few as 8 in 1981, but there has been a modest increase over the past two years, with DOE funding 49 nuclear engineering fellowships (including in health physics and fusion).

This pattern of decline in U.S. nuclear engineering education raises issues that may be vital to implementing U.S. energy policies and practices in the next 20 years. Will the decline in the number of programs continue? Has a "steady-state" condition been attained between the numbers of nuclear engineers being educated and the number that will be required? How will government and industry personnel needs change, if at all, in the next few decades? If demand increases, can programs expand readily to supply the needed personnel? Can any shortfall in supply be met by other physicists, radiochemists, or other engineering specialists? Are better students still being attracted to nuclear engineering? At the graduate level, will faculty research interests and activities be adequate to train the nuclear engineers likely to be in demand in the next few decades? Are current educational programs appropriate for future industry and government needs? What skills and education may be required for the next generation of nuclear engineers? These and similar questions motivated this study.

To better understand the history, status, and future of U.S. nuclear engineering education, the committee interviewed and surveyed experts from academia, industry, and government. It sought a variety of documents, presentations and data to further its work.

Three subcommittees or panels focused on major parts of the study's charge: the status of U.S. undergraduate and graduate education in nuclear engineering, with attention to such aspects as faculty age and research interests, and trends in student populations, curricula, instructional and research facilities, and funding; the educational needs of the next generation of nuclear engineers, with attention to curriculum changes that might be required and the adequacy of current university research programs; and projected personnel supply and demand for periods of 5, 10, 15, and 20 years in the future, for both military and nonmilitary segments of the federal government, industry, and academia. The results of these three panels were integrated to produce this report and its findings, conclusions, and recommendations.

These could serve to make available engineers who, with retraining, could meet some of the needs reflected in this report. However, at this point, the nature and the resultant effects are impossible to evaluate and the committee could not take this possibility into account.

FINDINGS AND CONCLUSIONS

The committee addressed a variety of issues to answer its charge. The following sections summarize the committee's findings and conclusions on nuclear engineering as a separate discipline, the status of nuclear engineering education, supply and demand issues, and future needs for nuclear engineering education.

Nuclear Engineering as a Separate Discipline

CONCLUSION: NUCLEAR ENGINEERING IS A BROAD, DIVERSE FIELD THAT IS VITAL AS A SEPARATE ENGINEERING DISCIPLINE TO U.S. NUCLEAR ENERGY PROGRAMS.

Committee findings that support this conclusion include the following:

- Nuclear engineering has unique academic requirements, including courses in reactor physics, reactor engineering, nuclear materials, reactor operations, and radiation protection.
- Nuclear engineering requires knowledge of an unusually broad combination of mathematics, physics, and engineering processes relative to other engineering areas.
- The complexities of reactor core physics, reactivity control, and radiation effects and protection tend to be handled best by nuclear engineers.
- Nuclear engineering research extends from applied nuclear science through the development of near-term nuclear technologies. The reach is analogous to the electrical engineer's study of broad applications of electromagnetic phenomena or the mechanical engineer's study of fluid mechanics.

Status of Nuclear Engineering Education

CONCLUSION: SINCE 1979, NUCLEAR ENGINEERING ACADEMIC PROGRAMS AT BOTH UNDERGRADUATE AND GRADUATE LEVELS HAVE DECLINED IN TERMS OF (1) THE NUMBER OF STUDENTS ENROLLING IN SUCH PROGRAMS, (2) THE NUMBER OF SCHOOLS OFFERING NUCLEAR ENGINEERING CURRICULA, AND (3) THE NUMBER OF RESEARCH REACTORS ON UNIVERSITY CAMPUSES.

Committee findings that support this conclusion include the following:

- Undergraduate senior enrollments in nuclear engineering programs decreased from 1,150 in 1978 to about 650 by 1988. Enrollments in masters programs also peaked in the late 1970s, at about 1,050 students, and steadily

declined to about 650 students in 1988. Since 1982, however, student enrollments in doctoral programs has remained relatively steady at about 600.

o The number of U.S. undergraduate nuclear engineering programs declined from 80 in 1975 to 57 in 1989.

o Two decades ago, 76 U.S. university research reactors were operating. By 1987, only 27 university research reactors were in operation at universities offering nuclear engineering degrees or options in nuclear engineering.

CONCLUSION: TRENDS IN NUCLEAR ENGINEERING PROGRAMS THAT ARE OF CONCERN INCLUDE: (1) A SHIFT IN THE RESEARCH FUNDING AWAY FROM AREAS RELATED TO POWER REACTOR TECHNOLOGY, (2) PROBLEMS IN MAINTAINING LABORATORIES AND EQUIPMENT IN SUPPORT OF NUCLEAR ENGINEERING EDUCATION, (3) THE AGEING OF EXISTING NUCLEAR ENGINEERING FACULTIES AND (4) THE DECLINE IN NUMBERS OF NEW JUNIOR FACULTY MEMBERS.

Committee findings that support this conclusion include the following:

o Currently less than 20 percent of funded research in nuclear engineering programs concerns power reactors, although the greatest demand for bachelor's of science and, to some extent, master's of science comes from the nuclear power industry.

o Because of the shift in research funding, graduate nuclear engineering education no longer focuses primarily on civilian nuclear power, but has broadened to include the utilization of nuclear processes and forces in diverse engineering applications, such as medicine, fusion, materials, and space applications.

o The lack of adequate funding for teaching laboratories and equipment has required curriculum changes, diversion of funds from research, and other actions, to maintain the facilities needed for nuclear engineering programs.

o The average age of U.S. nuclear engineering faculty is about 10 years greater than that of all engineering faculty, and only 18 percent of faculty qualified to teach nuclear engineering have less than 5 years of teaching experience. Failure to introduce young faculty will necessarily limit research development in many institutions and promises serious interruptions in future program continuity.

CONCLUSION: THE CONTENT OF NUCLEAR ENGINEERING CURRICULA IS BASICALLY SATISFACTORY, THOUGH A FEW MODIFICATIONS ARE SUGGESTED.

Committee findings that support this conclusion include the following:

o Nuclear engineering curricula cover more basic and other engineering sciences than other engineering programs. Formal course work in nuclear science is rarely required for students in other engineering disciplines, yet nuclear engineering curricula generally include more than five credit hours in each of chemistry, mechanics, electromagnetism and electronics, and thermal

sciences, enhanced courses in physics, and uniquely, additional required credits in nuclear science.

- o The content of nuclear engineering programs is generally appropriate for the needs of employers of nuclear engineering graduates at all levels.
- o A survey of organizations that hire undergraduate nuclear engineers indicates a desire for increased oral and written communication skills, better knowledge of the nuclear reactor as an integrated system, and greater understanding of the biological effects of radiation.

Supply and Demand

CONCLUSION: THERE IS NOW A BALANCE IN SUPPLY AND DEMAND FOR NUCLEAR ENGINEERS. HOWEVER, EVEN IF THERE IS NO DEMAND GROWTH IN THE FUTURE, SUPPLY WILL NOT SATISFY EXPECTED DEMAND IF PRESENT TRENDS IN NUCLEAR ENGINEERING EDUCATION CONTINUE.

Committee findings that support this conclusion include the following:

- o Current U.S. replacement needs for those with bachelor's, master's, and doctorate degrees in nuclear engineering are about 400 new labor market entrants annually. This demand roughly balances the current output of the educational system.
- o During the last decade, while the number of degrees awarded in quantitative fields increased at all degree levels, the number of B.S. and M.S. degrees awarded annually in nuclear engineering decreased. If current demand trends continue, a shortfall in supply will occur and grow with time.
- o The potential for increased demand is greater than the potential for increased supply, owing primarily to decreasing student populations. Significant shortages in nuclear engineers may be observed as early as the mid-1990s.

CONCLUSION: THE GROWTH IN DEMAND FOR NUCLEAR ENGINEERS OVER THE NEXT 5 TO 10 YEARS WILL BE DRIVEN BY EXPANDED FEDERAL PROGRAMS. THE PROJECTED INCREASE IN ANNUAL DEMAND OVER THIS PERIOD EXCEEDS THE CURRENT OUTPUT OF NUCLEAR ENGINEERING PROGRAMS. THE PROBLEM IS EXACERBATED IN MANY CASES BY THE REQUIREMENT OF U.S. CITIZENSHIP AND SECURITY CLEARANCES FOR EMPLOYMENT IN GOVERNMENT PROGRAMS.

Committee findings that support this conclusion include the following:

- o The expansion of federal programs in areas such as nuclear waste management and environmental remediation and restoration is expected to increase the annual demand for nuclear engineers by about 50 percent and 25 percent, respectively, in 1995 and 2000.
- o Although enrollment of foreign nationals in undergraduate nuclear engineering programs has dropped in the last decade from about 7 to about 2 percent, the non-citizen share of graduate student populations has been high in recent years. Currently the non-citizen share of master's and doctoral

candidates represent about 30 and 50 percent of total candidates, respectively.

o The employers of nuclear engineers that require U.S. citizenship and security clearances for employees (including the federal government, national laboratories, and weapons facilities) will be at a serious disadvantage in attracting quality graduates in the projected competitive hiring market.

CONCLUSION: BEYOND THE YEAR 2000, THE DEMAND FOR NUCLEAR ENGINEERS WILL DEPEND ON THE VIGOR AND TIMING OF ANY RESURGENCE OF COMMERCIAL NUCLEAR POWER. SUCH GROWTH COULD DOUBLE OR TRIPLE THE ANNUAL DEMAND FOR NUCLEAR ENGINEERS. THIS DEMAND WOULD GREATLY EXCEED THE OUTPUT OF CURRENT NUCLEAR ENGINEERING PROGRAMS EVEN IF THEY WERE TO EXPAND TO FULL CAPACITY.

Committee findings that support this conclusion include the following:

o If there is a resurgence of nuclear power, the committee's best-estimate projection is that the annual demand for nuclear engineers would increase at least 200 and possibly 300 percent between 2000 and 2010.

o Most nuclear engineering programs have the capacity for only modest expansion of either undergraduate or graduate populations without additional resources and faculty. To expand the undergraduate population would require diverting faculty and resources from the graduate and research programs and vice versa making major expansion at both levels together difficult. Undergraduate expansion is primarily limited by laboratory resources while graduate student expansion is primarily limited by resources for research and faculty for supervision. Continued erosion in faculty size over the next 5 to 10 years will limit institutions' ability to respond to increased demands for nuclear engineers in a timely fashion. Just using existing faculty engaged in sponsored research would require additional financial resources.

Training and Education for Future Needs

CONCLUSION: THE UNDERGRADUATE CURRICULUM FOCUSES ON POWER REACTOR SCIENCE AND TECHNOLOGY AND THIS EMPHASIS WILL CONTINUE TO BE APPROPRIATE IN THE FUTURE FOR MOST UNDERGRADUATE ENGINEERS WHO WILL ENTER THE UTILITY INDUSTRY OR THE ENGINEERING OR MANUFACTURING INDUSTRIES THAT SUPPORT THE UTILITIES. MODEST BROADENING OF THE CURRICULUM IS DESIRABLE TO ADDRESS EMERGING REQUIREMENTS IN ENVIRONMENTAL AND SAFETY AREAS. IN GRADUATE PROGRAMS, RESEARCH RELATED TO POWER REACTORS HAS DECLINED GREATLY AS AVAILABLE RESEARCH FUNDING HAS BEEN DIVERTED TO OTHER AREAS. RESEARCH RELATED TO POWER REACTORS NEEDS TO BE EXPANDED TO ENSURE THAT FACULTY RETAIN THE SKILLS AND ENTHUSIASM NECESSARY FOR THE UNDERGRADUATE CURRICULUM, WHICH IS DOMINATED BY POWER REACTOR TECHNOLOGY.

Committee findings that support this conclusion include the following:

o Bachelor of science graduates need strong skills in areas relating to nuclear power reactors because they are very likely to be employed in the

nuclear power industry. This is also true, though less so, of master of science graduates.

o Nuclear engineering curricula are properly focused on the fundamentals of the discipline but need modest broadening to respond to the following trends: the growing use of integrated systems approaches to evaluate reactor safety and risks, increased interest and concern about the biological effects of radiation, greater emphasis on radioactive waste management and related environmental remediation technologies, and the widely shared opinion of employers that graduates need improved oral and written communications skills (a concern common to all engineering disciplines and especially a problem given the many foreign students).

o Currently there is a broad employment market for Ph.D.s in nuclear engineering, with the power reactor industry playing only a modest role.

o Over the past 10 to 15 years, power reactor research has substantially declined. There has been some increase in research on fusion, space power applications, medical applications, and waste management. While research support levels are inadequate for the discipline, a broader-based research program on applications of nuclear forces and processes has emerged.

o There is a significant and growing mismatch between the research interests of the faculty and the subject matter of the undergraduate curricula.

o University research reactors have substantially declined in number over the past two decades. These reactors are important assets for training, research, and testing for the nuclear engineering programs that have them, and can substantially add to the undergraduate and graduate educational experience.

RECOMMENDATIONS

The responsibility for a viable nuclear engineering education system is shared by the federal government, private industry, and the academic community. Because the likely near-term shortage (in the next 5 to 10 years) of nuclear engineers would largely owe to expanded government programs, DOE has added responsibility for near-term solutions (also see Chapter 7, Summary and Recommendations). Based on the study's findings and conclusions, the committee offers the following recommendations to decision makers in the three responsible sectors.

Responsibilities of the Federal Government

o Funding for traineeship and fellowship programs should be increased.

o Additional research funds should be made available to support work on nuclear power reactors, especially for innovative approaches. Increasing the existing DOE research program from $4 million to $11 million per year is recommended.

o Programs to attract women and minorities into nuclear engineering should be enhanced, a need sharpened by demographic trends.

o DOE should consider providing funds for nuclear engineering participation in minority-oriented science and technology initiatives, notably those being established by the National Science Foundation.

o DOE should assess supporting the access, for educational purposes, of all nuclear engineering departments to the research reactors in the United States.

o DOE should ensure that its personnel data base in nuclear engineering, based on its Survey of Occupational Employment in Nuclear-Related Activities, promptly and accurately reflects supply and demand. Several actions should help accomplish this:

- The definitions of the discipline and job skill requirements should be revised and clarified to better match those used by the sectors being surveyed.
- Survey methods should be revised to ensure that no temporary assignments or offices are excluded and that all sectors of nuclear-related employment and all appropriate employees more generally are included.
- Survey questions and format should be reviewed both by professional questionnaire experts and by sector practitioners, to ensure thoroughness, consistency and clarity.
- The present exclusion from DOE personnel data of those in the fields of fusion, education and academia, and the health-care industry, and of uniformed military personnel should be reexamined.

Responsibilities of Industry

o While the projected near-term need owes largely to government programs, any increased longer term need for nuclear engineers is likely to arise from the resurgence of nuclear power. For this reason, electric utilities and the supporting industry should increase their participation and support to help ensure the supply of properly trained people their programs will require. Such support should cover cooperative student programs, research sponsorship, scholarships and fellowships, seminar sponsorship, and establishing and supporting academic chairs.

o Industry should continue working with the American Nuclear Society in support of its strong advocacy for nuclear engineering education, and with other professional societies, such as the American Society of Mechanical Engineers and the Institute of Electrical and Electronic Engineers, that support the industry through codes and standards.

Responsibilities of Universities

o Nuclear engineering curricula should continue to be broad based. At the undergraduate level, however, programs should increase their emphasis on systems-oriented reactor engineering, study of the biological effects of

radiation, and oral and written communication skills. At both undergraduate and graduate levels, more emphasis should be given to nuclear waste management and environmental remediation and restoration.

o Research programs should include more research in reactor-oriented areas.

o Nuclear engineering faculty should actively develop and seek support for research related to power reactors, nuclear waste management, and environmental remediation.

o University administrators should develop innovative procedures, such as partial or phased retirement of older faculty to retain access to their special capabilities and skills, to allow the addition of junior faculty in a timely fashion.

Mrs. LLOYD. Thank you very much, Dr. Jones. As you know, the subcommittee has been exploring the possibilities of combining the Nuclear Engineering Research and Education Program and the University Research Reactor Program into one comprehensive program.

Would you give me your comments on this idea?

Dr. JONES. I can give you mine. We don't see anything incompatible because we have been working closely together for the last three years. We have been jointly proposing budgets to you and to the Department of Energy. We think the programs are compatible. Both studies suggested that there is compatibility between the University Research Reactors and the Education Programs.

Mrs. LLOYD. Mr. Morrison.

Mr. MORRISON. I am interested, gentlemen, if you believe that you will see an upswing in the interest of nuclear engineers as, hopefully, the orders for reactors begin to flow later in this decade.

Have you anticipated that? And have your working relationships with industry reflected these needs?

Dr. JONES. We have anticipated it. Our working relationships, as I have indicated, with industry, I think, are on the rise.

The projections for the need have been, I believe, well clarified in the report by the National Academy. A table in there is included in terms of projected needs, in one of the attachments to my testimony, that shows as soon as new orders start, there will be a significant increase. I have already indicated there is an increase due to the waste clean-up.

If the space program becomes well funded in terms of deep space exploration, that will require the nuclear option also. Putting those three together, there are very large projections for increase.

Mr. MORRISON. Dr. Voth, do you concur?

Dr. VOTH. I concur with that. I might add that from a facilities standpoint, we expect this increase in the people coming through in the education area in nuclear engineering education, there is a steady baseload in addition to that, that we see, in all of the sciences finding nuclear applications. That has not changed. That is a very stable and I expect it to continue and if anything increased in terms of reactor users.

Mr. MORRISON. Is there a way that—as we look to the future—that if on-campus reactors are not going to be part of that future, that we could possibly centralize some part of this training. I know that complicates life from your point of view, but is that a possibility?

Dr. VOTH. We have looked at it from the standpoint of facilities. Dr. Jones may wish to comment from the sake of education, as well.

In a facility, we do a lot of programs with adjacent colleges, adjacent high schools, who are infrequent users. The experience has been that a 50 to 80 mile radius is a practical maximum. A hundred miles is pretty much limiting. Beyond that, programs particularly to bring students in to use reactors effectively is impractical.

So from that standpoint, what experience has shown is that where you have a strong program in nuclear engineering education, there is a reactor. Where you have a very actively used reac-

tor, there is a program in nuclear engineering education. The two are almost inseparable in terms of building each other.

In that context, I have not seen a proposal where this concept could work, unless, for example, you are in a situation like the University of Tennessee being in proximity to Oak Ridge where you can use those facilities and in the State of Washington, you may have similar examples, but in most states, that is not a practical alternative, in my opinion.l

Mr. MORRISON. Dr. Jones.

Dr. JONES. I concur with that. I think when you look at the utilization of reactors, there are certain types of activities that university reactors cannot provide in general. They are typically not competing with the Advanced Neutron Source or the High Flux Facility at Oak Ridge.

However, those have limited capabilities of really working closely with education programs, other than very specific advanced research levels. What we see at the universities are much broader based than a few specific examples of research programs.

The proximity is critical. Dr. Voth is absolutely correct in that. When we look at the type of interactions that we see on our campus, it is all over the campus that the utilization of a reactor can occur. It doesn't have to be a tens of megawatt reactor to do that. It can be relatively low power and provide trace elements of very short half-lifes and so on. These are used on-campus by ongoing research programs. Those would not fit the pattern of centralized programs in the country.

Mr. MORRISON. Dr. Voth.

Dr. VOTH. I might add one other comment, if I might. That is when Dr. Jones was talking about the size factor or the complexity. When you look at the dollar numbers that I was quoting and you look at the dollar numbers, for example, that Dr. Decker was quoting, you are orders of magnitude apart. It is simply too expensive to designate an Advanced Neutron Source or a HFER for significant educational functions. Those can be done most economically at a reactor that costs one or two percent of the operating costs of the larger facilities. They do a very good job of that.

Likewise, the advanced facilities that we talk about need people who are trained to come in to operate those facilities. They need people who are trained on smaller reactors possibly, but that know the basics. You cannot efficiently and economically train researchers on the large reactors.

Mr. MORRISON. Thank you.

Madame Chairwoman, I wish there was a better answer. On this, I think we are going to have to invest.

Mrs. LLOYD. I think you are probably right.

Mr. Fawell.

Mr. FAWELL. Yes. My feelings, too. I see the suggestion of $17 million, but they offer $1 million if I heard the testimony correctly.

Let me ask this question, and it is a question borne of ignorance more than anything else, I would assume since I am a lawyer wandering out of the field of liberal arts and science.

You have testified, Dr. Voth, that a total of 71 research reactors and it is down to 37. In other words, a number of imminent schools,

which have undergraduate and graduate work in regard to nuclear energy are apparently functioning without research reactors now.

To what degree does that cut the overall quality of your educational product? Would you compare what the European comparable schools face in that regards? Are they facing some of these problems or do they all have a research reactor? It is strictly a layman's question.

Dr. VOTH. With respect to the programs that operate without a reactor, I will defer part of that question to Dr. Jones, who works with the nuclear engineering education more so than myself, who works primarily with facilities.

One observation I have made, though, is that the trend has been if a nuclear reactor closes, the departments of nuclear engineering will frequently get absorbed in another department and it may move from a department to a program. Within a matter of a decade or much less, it may be abandoned. So I think that is what the trend is.

If you look at the strong programs in nuclear engineering, they will be accompanied by a strong reactor program.

The other point that you raised about the European experience, in my testimony, I do include some numbers for the expenditures for foreign research reactors. They are substantially greater. We falling behind even third world countries in reactor capabilities.

With respect to the way that they are using educational programs, they, in many cases, have a close network between the university, the national research or the national lab equivalent, and their national research program. What you will find is that people will use the small reactors at universities and do much of the graduate level research at the equivalent of national laboratories. It is a slightly different structure. This is also discussed in the Academy study on the subject.

Mr. FAWELL. Are there examples of schools, though, still of high excellence, although they do not have a university research reactor?

Dr. VOTH. There are a couple of examples that are right in the process. One has been an experiment for some time, if you will. That is UCLA. They chose to shut that reactor down at the time of the Olympics in the early 1980s. Their program is included in aerospace and mechanical engineering. It turns out to be not a large program. I am not quite sure that there is a good measure of the influence on that.

A more striking example is the one at Berkeley that has recently closed their reactor. But they are converting their facility into another source structure from which they acquired from Lawrence-Livermore. So they are sitting much the same way the University of Tennessee is—adjacent to a large national laboratory or at least within a few hours driving time, an hour's driving time.

Mr. FAWELL. I was just trying to settle it in my own my mind. I realize it is a demerit and a negative, but I was wondering: Are we disseminating the programs? Or are we just making it that much more difficult? I assume there is still some excellence going on out there, even though one doesn't have access to a research reactor.

Dr. VOTH. It makes it harder. It makes it harder to train the students because they lose that particular experience and it limits the type of research that can be conducted.

Mr. FAWELL. Certainly, when you have a decline of two per year and you have gone from 71 down to 37 located at just 33 sites, there certainly has been a negative there. I wish I could wave a wand here and take care of it, too.

I appreciate the testimony. I have learned something.

Thank you.

Mrs. LLOYD. Thank you very much, gentlemen, for being with us. We will be submitting questions for the record in writing. I appreciate having you with us today.

Panel III will be testifying on materials science. Joining us today are Dr. Frank Fradin, Associate Laboratory Director for Physical Research for the Argonne National Laboratory; Dr. Martin Blume, Deputy Director of Brookhaven National Laboratory; and Dr. Michael Knotek, Senior Science Director from Pacific Northwest Laboratory.

We are very pleased to have you gentlemen with us. Please proceed. We will submit your entire statement for the record so that you may summarize your testimony.

Dr. Fradin, would you begin?

STATEMENT OF DR. FRANK Y. FRADIN, ASSOCIATE LABORATORY DIRECTOR FOR PHYSICAL RESEARCH, ARGONNE NATIONAL LABORATORY

Dr. FRADIN. Yes. Thank you, Mrs. Lloyd, Mr. Morrison, Mr. Fawell. Thank you for the opportunity to speak before you today.

In addition to being responsible for materials research at Argonne, I have worked 25 years in materials research both as a scientist and as a research director. I would like to speak to you today about the national needs in materials research and about the Department of Energy's response.

First, I would like to describe some of the conclusions of the Materials Science and Engineering Study that was recently completed for the National Academies of Sciences and Engineering and the report of the regional implementation groups.

The implementation calls for increased university, industry, government laboratory cooperative research. It also points out that synthesis and processing is one of the areas that the U.S. is relatively weak in and needs to bring up its efforts. This is an underlying theme of many of the technical opportunities that are pointed out as national needs, which includes materials areas such as miniaturization of devices for electronic communications, structural materials and advanced materials for energy conversion and conservation.

Argonne's material sciences program has been very active in developing collaborative research with both industries and universities. I will give you a couple of examples of these. Argonne, together with the University of Illinois, Northwestern University and the University of Chicago, has formed a National Science and Technology Center for superconductivity, whose goal is to advance the science of high temperature superconductors. This brings together

some of the best scientists in the U.S. in this area to treat complex materials issues. It also acts as a focussing point for education of bright young students into this multi-disciplinary environment.

In the area of industrial interaction, through the superconductivity pilot center, Argonne's materials science researchers work in collaborative teams with such companies as General Electric, TRW, MCC, American Superconductor Corporation, et cetera, in this fast moving area to, in fact, advance the commercialization of high temperature superconductors. This is particularly important in a fast-moving field where we compete with the Japanese and Europeans.

Argonne's material science staff has also been very active in licensing a number of patents to industries and in fact, in spinning off new venture start-ups, such as Nanophase Technologies and Illinois Superconductor Corporation. These are new companies that are adding to the country's commercial competitive position.

Argonne's material science program has been a leader in the development of novel synthesis and processing techniques for advanced materials. In recent years, these materials have become of increasing importance in the commercial sector.

With its strong base, Argonne has proposed a center of excellence and synthesis in processing, which would be leveraged from the existing Basic Energy Sciences, Materials Science Program. Funding of $5 million per year was requested for this initiative to begin in fiscal year 1991. The center would develop collaborations with the other multi-program laboratories and with selected universities and industries with the goal of early commercial impact in these new advanced materials.

Well, that's the good news. Unfortunately, I have to bring you some bad news as well.

The Materials Science and Engineering Report has shown a decline in Federal non-defense support for materials research of 21 percent in inflation adjusted dollars since 1976. This decrease is particularly surprising since materials are vitally important to our economic security. Virtually all new technologies are driven by advances in materials.

To be more specific, the Basic Energy Sciences, Materials Science Program is a major source of funding for long-term research in materials that underpin energy technologies. This funding, both at national laboratories and universities has been declining in inflation adjusted dollars since fiscal year 1988. In the same period, the Materials Science Program has had the responsibility to underwrite significant increases for major facilities. These facilities not only support materials research, but support biological, medical, chemical defense, et cetera. All these other research enterprises at these facilities are supported by Materials Research.

Let me crystalize this for you by using Argonne as an example of the impacts on the Materials Science Research Program. Our situation is similar to that which occurs at the other multi-program laboratories represented here.

Facility operating funds for Argonne's Advanced Photon Source has grown in recent years. Funds for the major facility of the Intense Pulse Neutron Source at Argonne has kept pace with inflation. In contrast, the materials science research component at Argonne has had flat dollars since fiscal year 1988. This means that

approximately one-quarter of the research program has been lost to inflation since fiscal year 1988.

Unless this trend is reversed, the impact on this center of excellence in materials research is that programs that support DOE initiatives in advanced synthesis and processing of, for example, structure ceramics, novel electronic materials, high temperature superconductors, will be curtailed. Also, material science activities that make use of the unique abilities of these major facilities will be lost. The scientific talent, once lost, will be very difficult to replace.

Finally, I would ask this committee to consider immediate action on enhancing the fiscal year 1992 budget for the Basic Energy Sciences, Materials Sciences Program. The programmatic losses to long-term research in materials science that are driven by a constant dollar budget for the research component would result in a loss of talent and productivity which will have a severely negative impact on materials research programs. This would occur just at the time when Dr. Bromley, the President's Science and Technology Advisor, has called attention to the need to recapture our Nation's competitive position in materials R&D.

An increment of $12 million or about ten percent of the fiscal year 1992 Materials Sciences research component focussed on materials synthesis and processing would be an excellent statement by your committee regarding research priorities and their impacts on industrial competitiveness.

Thank you. I would be willing to answer questions.

[The prepared statement of Dr. Fradin follows:]

Testimony of

Frank Y. Fradin
Associate Laboratory Director for
Physical Research
at
Argonne National Laboratory

before
the House Science, Space & Technology
Committee
Subcommittee on Energy

March 19, 1991

Madame Chairperson and members of the Subcommittee. My name is Frank Fradin, I am the Associate Laboratory Director for Physical Research of Argonne National Laboratory with responsibilities that include materials research. I have worked 25 years in materials research both as a scientist and as a research director. I am currently a member of the steering committee of the Materials Physics Division of the American Physical Society and I am active in the Materials Research Society. I would like to speak to you today about the national needs in materials research and the response of the Department of Energy.

First, I would like to describe a number of conclusions of the Materials Science and Engineering (MS&E) Study of the National Academies of Sciences and Engineering and the report of the regional implementation groups "A National Agenda in Materials Science and Engineering." The implementation calls for increased industry, university, government laboratory cooperative research. Synthesis and processing, which was identified in the MS&E report as a serious weakness in the U.S. is an underlying theme in many of the technical opportunities in areas of national need. These are:

information/communication: miniaturization of electronic devices

transportation: design and manufacturing of structural materials

energy: advanced materials for energy conversion and conservation

health: biocompatible materials

environment: environmentally benign materials

maintaining leadership in materials research: complex materials.

The study indicated that accomplishing these initiatives would require 1.25B$ per year over what is now spent on materials R&D. Estimates place R&D in materials by industry, government, etc. at over 3B$ per year.

Argonne's materials science program has been very active in developing collaborative research partnerships with universities and industries. To give a few examples, Argonne together with the University of Illinois at Champaign-Urbana, Northwestern University and the University of Chicago formed the National Science Foundation—Science and Technology Center for Superconductivity whose goal is to advance the science of high temperature superconductors. This Center brings together some of the best scientists in the U.S. into a working environment where complex materials issues can be solved and students can be educated in an exciting multidisciplinary environment.

Through the Superconductivity Pilot Center, Argonne's materials science researchers work in collaborative teams with industrial research laboratories such as General Electric, TRW, and MCC to bring high temperature superconductors more quickly into commercialization, thus helping the U.S. to compete against the Japanese and Europeans in this fast moving field. Argonne's materials science staff have in recent years licensed a number of patents to industry (e.g. STREM Chemical Co., American Superconductor Corp., etc.) and have spun off new companies such as Nanophase Technologies, Inc. and Illinois Superconductor Corp.

Argonne's materials science program has been a leader in the development of novel synthesis techniques for advanced materials. In recent years synthesis activities have included development of unique materials of high potential importance in the commercial sector. A few examples include: artificial metallic superlattices were invented at Argonne

and have important implications as sensors and monochromators; new hybrid zeolite-type catalysts combining molecular sieve principles with active metal catalysts for enhancing specific reactions have been designed at Argonne and are of importance to the petrochemical industry; Argonne scientists have developed new techniques of metal organic chemical vapor deposition for making electro-optically active ceramic multilayer devices that will have important implications for high speed communication; new nanophase materials for structural ceramics and for catalysts have been developed at Argonne and are the basis of a new venture company; advanced design principles for synthesizing new organic conductors has been active at Argonne and represents the only significant U.S. effort competing with the Japanese. With this strong base, Argonne has proposed a Center of Excellence in Synthesis and Processing which can be leveraged from existing efforts in the BES-Materials Science Program. This initiative would include engineered materials, metastable phases, synthesis under extreme conditions, and the growth of perfect crystals of complex materials. Funding of 5M$ per year for this initiative was requested for initiation in FY 1991. The Center would develop research collaborations with the other multiprogram laboratories, as well as with selected industries and universities with the objective of early commercial impact.

However the MS&E report shows a decline in Federal nondefense support for materials research of 21% in inflation adjusted dollars since 1976. This decrease is particularly surprising since materials are vitally important to our economic security. Virtually all new technologies are driven by advances in materials.

To be more specific, the DOE Basic Energy Sciences (BES)—Materials Sciences Program is the major source of funding for long-range research in materials that underpins energy technology. This funding at national laboratories and at universities has been declining in inflation adjusted dollars since FY 1988. In the same period this Program has had the responsibility to underwrite significant increases in expenditures for major facilities that support not only materials research, but also biological, medical, chemical, defense and a variety of other research enterprises.

Let me crystallize this for you by using Argonne as an example of the impacts on the Materials Sciences Research Program. Our situation is similar to that at the other multiprogram laboratories, e.g. Oak Ridge National Laboratory, Lawrence Berkeley Laboratory, and Brookhaven National Laboratory, that have responsibilities for major facilities as well as research programs supported by BES—Materials Sciences. Facility operating funds for Argonne's Advanced Photon Source (APS) have grown (from 4.7M$ in FY 88 to 24.3M$ in the FY 92 President's Budget (PB)) and the Intense Pulsed Neutron Source (IPNS) has kept pace with inflation (5.1M$ in FY 88 to 6.8M$ in FY 92 PB). In contrast the materials science research program has had flat dollars (17.2M$ in FY 88 to 17.1M$ in FY 92 PB). This means that during a period of roughly 6% annual inflation, approximately one-quarter of the research program has been lost.

Unless this trend is reversed, the impact on this center of excellence in materials research is that programs that support major DOE initiatives in advanced synthesis and processing of, for example, high temperature superconductors, novel ceramics, nanophase, and lower dimensional materials will be curtailed. Also materials science activities that make use of the unique abilities of the major facilities, IPNS and APS,

for in situ studies of materials synthesis and materials properties will be lost. The scientific talent once lost will be very difficult to replace.

Finally, I would ask this Committee to consider immediate action on enhancing the FY 1992 budget for BES-Materials Sciences. The programmatic losses to long term research in materials sciences that are driven by a constant dollar budget for the research component would result in a loss of talent and productivity, which will have a severely negative impact on materials research programs. This would occur just at the time when Dr. Bromley, the President's Science Advisor, has called attention to the need to recapture our Nation's competitive position in materials R&D. An increment of 12M$, or about 10% to the FY 1992 BES-Materials Sciences research budget, focused on materials synthesis and processing would be an excellent statement by your Committee regarding research priorities and their impacts on industrial competitiveness.

Mrs. LLOYD. Thank you very much.
Dr. Blume.

STATEMENT OF DR. MARTIN BLUME, DEPUTY DIRECTOR, BROOKHAVEN NATIONAL LABORATORY

Dr. BLUME. Thank you. Madame Chairwoman, distinguished members of the committee, I am happy to testify on the Materials Science budget of the Department of Energy as part of the Basic Energy Sciences Programs.

I would like to say in advance that I had not seen Dr. Fradin's testimony before I came here, and so there should not be any indication of a conspiratorial agreement between us. It just happens that I am going to say some very similar things.

Mrs. LLOYD. Sometimes we ask the same questions.

Dr. BLUME. The Materials Science funding of the DOE goes for two principal purposes. First, it provides money for research programs at National Laboratories and Universities. Second, it supports the construction and operation of the major research facilities, like synchrotron radiation sources, neutron sources and large electron microscopes.

These two purposes are essential components of a successful research and development program in materials science. It is, in a sense, artificial to consider them separately. Researchers, after all, need access to the best possible facilities and outstanding facilities are unproductive without talented researchers to use them.

Scientists also need smaller equipment for many parts of their research efforts. Indeed, many experiments do not make use of these large facilities at all—many very important ones, in areas such as superconductivity and synthesis and processing. Striking a proper balance between these in a time of funding stringency is difficult.

It is made even more difficult by the demands of facilities for services, upkeep and by heightened need for safety and environmental protection support. These demands must be met. They increase at a rate that far exceeds inflation.

The DOE has provided a good increase for the Materials Sciences Programs, but because of the insistent requirements of the facilities, the net effect has been to provide little for the general research efforts. New initiatives in areas that are important but peripheral to material science, like high performance computing, have also had a budgetary impact on the research program.

The funding for the core research programs is the same for fiscal year 1992 as it is now for fiscal year 1991. The situation could be dealt with for a single year, but for the past six years, the funding of the core programs at the National Laboratories and at the Universities has, with minor fluctuations, failed to keep pace with inflation.

The predictable result has been staff reductions that hit vigorous, effective research programs. Until now, these reductions have hit hardest at the level of the young post-doctoral scientist, a development which will have damaging repercussions for many years to come. The contraction is now spreading to more experienced scien-

tists as well, and many programs are balanced on the brink of their minimum effective size.

We must clearly face the fact that we cannot build and operate our facilities and embark on new initiatives without damaging these core efforts, and ironically, without weakening the cadre of users of these facilities.

As I look ahead, I see many opportunities for the development of new materials. These have been extensively documented in the NRC study, "Material Science and Engineering for the 1990s," which has already been discussed before this committee.

In a series of regional follow-up meetings, our research community has produced an action plan: "A National Agency in Materials Science and Engineering." This document describes opportunities for research that are driven by several technological end uses, such as transportation uses for designing and manufacturing of structural materials and advanced materials for energy conservation.

I enthusiastically endorse such an initiative which would probably be proposed for fiscal year 1993, but I would like to make one caution. Not all research should be driven by technological end uses. This method of setting priorities should not be used simply to redefine and redirect funds in this productive Basic Energy Sciences based program. We should instead maintain this program at a good level of strength because of the long-range opportunities it addresses and because it provides the underpinning for solutions to problems that have yet to be recognized.

In the area of user facilities, there are two forefront DOE facilities located at Brookhaven, the High Flux Beam Reactor, which is used for neutron scattering studies of materials and the National Synchrotron Light Source, which is currently the world's premier Synchrotron facility.

The Synchrotron Light Source provides intense beams of X-rays and ultra-violet radiation and is, in a sense, the forerunner of the facilities that we will hear about in the next panel discussion.

I do have in my testimony a photograph of a very intense beam of X-rays that, in fact, is now the most intense such beam in the world. It presages what will be seen in the facilities to come in the future.

There are more than 2,000 users of the Light Source who come from a wide range of universities, government laboratories and industrial laboratories. Last year, approximately a thousand experiments were performed. The number of technical papers published in the scientific literature based on work at the Light Source has reached the rate of approximately one paper per day. In fact, there were 364 papers published last year. I think someone took the 4th of July off in order to give me something extra to say at this point.

There are many different technological applications. One of interest to those of us in the relevant age group is a picture of the coronary angiogram taken without an invasive catheter. This is work that was pioneered at Stanford and that has been moved to Brookhaven now. They have successfully now imaged the hearts of human patients. This work is ongoing.

All in all, we are pleased with the support that has been given to the Light Source in the President's budget. I know it will startle the committee to hear this, coming from a scientist, but it is the

fact. There are, of course, always things we could do with more resources, but we recognize the difficulties of the fiscal situation and the priorities that must be given to the core programs.

The High Flux Beam Reactor, which is our source of neutrons for materials research, is expected to restart next month after a long shut-down for reevaluation of safety systems and procedures. While adequate funding is provided for operation of the reactor, we are disappointed at the failure to include the experimental equipment upgrade, which would have covered facilities at the High Flux Isotope Reactor at Oak Ridge, as well as the HFBR at Brookhaven in the Presidential budget. Nevertheless, we understand the situation because of the priorities that have to be given to the core programs.

I would like, in concluding my testimony, to address one point. This is the question of user fees at the facilities. Most of us who are involved in the operation of these facilities regard user fees as a serious threat to technology transfer and an extreme complication in the operation of these facilities.

Congress has mandated a study of the feasibility of charging fees for the use of the user facilities. There is also, as I understand it, some sentiment in the Department of Energy for such charges in the hope that the funds collected will alleviate budget problems. Such fees, we believe, would be counter-productive in that they would discourage industrial use of the facilities and would not produce very much revenue.

All in all, the policy questions that have to be addressed in considering user fees are these. It is clearly in the DOE interest to encourage industrial participation in long-term basic research. Most industrial research laboratories would not take part in such research without considerable inducement since they take a relatively short range approach to the type of research they support.

The Government spends a lot of money to have basic research performed, taking the form of grants and contracts at universities, national laboratories and not-for-profits. By not charging fees to industrial users, the Government is leveraging its funds for facility operation by the expenditure by industry for staff and support salaries and for experimental equipment. In addition, the Government by doing this encourages technology transfer, a prime policy objective.

Finally, the net impact of charging user fees for operating costs would be to discourage this industrial participation, to establish a cumbersome and costly process if it is applied to university researchers and to lose for the Department of Energy the experimental equipment, the intellectual resources and the educational benefits that would come from research on problems of programmatic interest to DOE by these users.

Thank you.

[The prepared statement of Dr. Blume follows:]

Testimony of

Martin Blume

Deputy Director
Brookhaven National Laboratory
Upton, NY 11973

Before the Subcommittee on Energy
U.S. House of Representatives
Committee on Science, Space and Technology

March 19, 1991

It is an honor to have the opportunity to testify before this distinguished Committee on the Basic Energy Sciences programs of the Department of Energy. I will, as requested in your invitation to appear here, focus specifically on the efforts of the Department in the area of materials science.

The materials science funding of the DOE goes for two principal purposes. First, it provides money for research programs at National Laboratories and Universities, and second, it supports the construction and operation of major research facilities ("user facilities") like synchrotron radiation sources, neutron sources and large electron microscopes. These two purposes are essential components of a successful research and development program in materials science, and it is, in a sense, artificial to consider them separately. Researchers, after all, need access to the best-possible facilities, and outstanding facilities are unproductive without talented researchers to use them. Scientists also need smaller equipment for many parts of their research efforts. Striking a proper balance between these in a time of funding stringency is difficult. It is made even more difficult by the demands at facilities for services, upkeep and by a heightened need for safety and environmental protection support. These demands must be met, and they increase at a rate that far exceeds inflation. The DOE has provided a good increase for the materials science programs, but because of the insistent requirements of the facilities, the net effect has been to provide little for the general research efforts. New initiatives in areas that are important but peripheral to materials science, like high-performance computing, have also had a budgetary impact on the research program.

Health of the Core Research Programs

The funding for the core research programs is the same for the FY'92 Presidential budget as it now is for FY'91. This situation could be dealt with for a single year, but for the past six years the funding of the core programs at the National Laboratories has, with minor fluctuations, failed to keep pace with inflation. The predictable result has been staff reductions that hit vigorous, effective research programs. Until now these reductions have hit hardest at the level of the young post-doctoral scientist, a development which will have damaging repercussions for many years to come. This contraction is now spreading to more experienced scientists as well, and many programs are balanced on the brink of their minimum effective size. We must clearly fact the fact that we cannot build and operate our facilities and embark on new initiatives without damaging these core efforts and ironically, without weakening the cadre of users of these facilities. We and the DOE must set priorities.

Congressional Redirection of Funds

The predicament that I have described is one that holds for the budget proposed by the President. I must point out that in each previous year the situation has been exacerbated by Congressional action. Funds have been redirected to other projects which have in many cases little relation to materials science or basic energy sciences. I fully understand that there are compelling

arguments for these actions, but they should be debated in a forum where their merits can be evaluated fully. I earnestly hope that you will not allow these projects to go forward without separate funding that does not come out of the materials science effort.

New Initiatives in Materials Science

As I look ahead, I see many opportunities for the development of new materials. These have been extensively documented in the National Research Council study, *Materials Science and Engineering for the 1990's*, which has already been discussed before this Committee. In a series of regional follow-up meetings, our research community has produced an "action plan": *A National Agenda in Materials Science and Engineering*. This document describes opportunities for research that is driven by several technological end uses, such as transportation uses for designing and manufacturing os structural materials and advanced materials for energy conservation. This report has been accepted by the President's Science Advisor, Dr. D. Allan Bromley, and we expect an initiative on this subject to be proposed for FY 1993. I enthusiastically endorse such an initiative, with but one caution. Not all research should be driven by technological end uses. This method of setting priorities should not be used simply to redefine and redirect funds in the productive BES base program. We should instead maintain this program at a good level of strength because of the long-range opportunities it addresses and because it provides the underpinning for solutions to problems that have yet to be recognized.

The appropriate place for funding and oversight of technologically driven materials research is in the DOE's technology secretariats. Thus a program resulting from the requirements of conservation should be part of the R&D effort overseen by the Assistant Secretary for Conservation, and materials problems arising from an end use in, say, a nuclear rector, should be the responsibility of the Assistant Secretary for Nuclear Energy. Since there is relatively little experience in these organizations in handling materials research, it is essential for them to make use of the Basic Energy Sciences and its Division of Materials Sciences and in the OER National Laboratories for which they are responsible. In this way DOE will be able to integrate the materials requirements of the different technologies and the research programs that they drive, without diluting the very effective, but overburdened, long-range research efforts of BES. Also, by making use of the expertise and facilities that BES has provided at the OER National Laboratories, the technology programs can leverage their resources by building their programs on the already existing BES-funded efforts.

User Facilities

Two of the forefront DOE user facilities are located at Brookhaven National Laboratory. These are the High Flux Beam Reactor, which is used for neutron scattering studies of materials and the National Synchrotron Light Source currently the world's premier synchrotron facility. I will discuss them separately.

The **National Synchrotron Light Source** provides very intense beams of x-ray and ultraviolet radiation for experiments in virtually all branches of the physical and biological sciences. There are seventy-nine operational experimental stations. Figure 1 shows the beam from one of the seven so-called insertion devices (wigglers and undulators). The x-ray beam is so intense that it ionizes the air, illuminating the beam so that appears in the photograph as a blue line. That beam has the highest power density of any synchrotron beam in the world at this time, and it requires a specially cooled monochromater to withstand the heavy heat load.

There are more than 2,000 users of the NSLS who come from a wide range of universities, government laboratories and industrial laboratories which are spread throughout the United States. Last year approximately 1,000 experiments were performed, and the number of technical papers published in the scientific literature, which are based on work done at the NSLS, has reached the rate of approximately one paper per day. The NSLS has become a truly exciting intellectual center which trains students and provides crossfertilization between the university and industrial communities. Let me give you a few examples of the diverse areas in which synchrotron radiation is having broad impact. In the area of medicine, there is a program to develop a much less invasive form of coronary angiography. Recently a team of doctors and scientists has studied post-angioplasty patients, and they were able to see how the coronary artery remained open in one patient and closed in another several years after the operation. Figure 2 shows one of the coronary angiograms obtained at the NSLS. This program, pioneered at Stanford, has been moved to NSLS to take advantage of the facilities there. In the area of geophysics, studies of the structure of materials under conditions that mimic those in the mantle of the earth are leading scientists to question established theories of mantle flow.

The electronics industry is pursuing the manufacture of semiconductor chips using the process of x-ray lithography as a possible high throughput technique for the 21st century. Both IBM and AT&T Bell Laboratories have programs to develop this process. IBM has put a prototype processing facility in place at the NSLS and has successfully manufactured specialized chips with less than 0.5 micron feature sizes. AT&T has been developing the technique of projection lithography and has demonstrated the ability to obtain features as small as 0.05 microns. Both of these achievements are well below the feature sizes used in the current generation of computer chips. The NSLS has support from DARPA to develop a U.S. synchrotron-based source for x-ray lithography and to provide the technology transfer to our industrial partners, Grumman Electronics Systems and General Dynamics Space Sciences Division. The semiconductor industry will then be able to obtain such sources should they switch over from the present optical lithography systems to x-ray lithography. Figure 3 shows the warm version of a compact synchrotron that was commissioned last fall at the NSLS and which has reached about twice its design current.

The properties of surfaces are not only of current scientific interest, but also of industrial importance. The high flux and the ability to tune the x-ray energy continuously over a broad range have enabled scientists to study many different aspects of surface science at the NSLS. To begin with, the layers of atoms at the surface are not arranged in the same way as those further inside the bulk of the material. These are more than half a dozen experimental stations which are devoted to the study of the arrangement of the atoms at the surface of metals and semiconductors or at the interfaces between different solids or between solids and liquids, as for example in electrochemical cells. These studies, in turn, form the basis for understanding the electronic properties of surfaces which are determined in different experiments at the NSLS and which are important to our understanding of things as diverse as semiconductors or catalysts.

In the end, we all like to see pictures of objects, and there has always been a push to see things on a smaller and smaller scale - preferably in a non-destructive way. There are more than a dozen different types of imaging being done at the NSLS. I have already referred to coronary angiography, but that is only one form of imaging. Using various forms of tomography, scientists are able to study not only the distribution of elements in a sample, but also even the distribution of the valence of an element in a mixture. A photoelectron microscope has been developed and has been used to make a picture of a silicon substrate on which strips of aluminum and silicon dioxide have been deposited. The microscope shows not only where the silicon is, but which parts are pure silicon and which parts are silicon in silicon dioxide. A group from Exxon studies the distribution of sulfur and the porosity of coal, and several different oil companies study the composition of various catalysts. Geophysicists study the distribution of trace elements in meteorites, and doctors study the distribution of lead in bones. Soft x-ray microscopes are used to study biological samples in solution rather than in a dried state, as required in electron microscopes.

All in all, we are pleased with the support given to NSLS in the President's budget. (I know it will startle the committee to hear this!) There are, of course, always things we could do with more resources, but we recognize the difficulties of the fiscal situation and the priorities that must be given to the core programs.

The **High Flux Beam Reactor**, our source of neutrons for materials research, is expected to restart after a long shutdown for re-evaluation of safety systems and procedures. While adequate funding is provided for operation of the reactor, we are disappointed at the failure to include the Experimental Equipment Upgrade in the Presidential budget.

The HFBR still serves the needs of a broad spectrum of scientists from government laboratories, universities and industry conducting frontier research in chemistry, physics and life sciences. But as the Brinkman Committee first

noted in 1980 and the Rush and Seitz/Eastman Committees re-emphasized four years later, even though the reactor itself remains one of the world's premier steady state neutron sources, much of its experimental equipment is becoming outmoded. To replace it, the Laboratory has proposed a four-year, $20.8 million plan for new instrument construction. Carried to completion, this plan would not only bring the performance of the reactor's instrumentation up to contemporary standards, but would provide new facilities for a more expanded and broader-based research program. Moreover, it would offer a timely opportunity to explore and evaluate new spectroscopic concepts to assure that the research facilities of the Advanced Neutron Source represent the latest and best in state-of-the-art instrument development.

As the only steady-state reactor in the United States with a liquid hydrogen moderator, the HFBR is particularly well-adapted to investigations employing subthermal neutrons. To enhance its capability in this increasingly important field, the Laboratory proposes building a new cold moderator beam plug to bring three subthermal beams of the largest practical size out of the reactor. The neutrons would be conducted by guides to three new instruments (a high resolution time-of-flight spectrometer, a high resolution small-angle-scattering spectrometer and a medium resolution small-angle-scattering spectrometer) and to two existing instruments (a triple-axis spectrometer and a reflection spectrometer), both of which would be substantially reconfigured to improve their performance. Apart from this, a special instrument development station would be installed at the end of one of the guides. Initially intended as a facility for the study of new instrumental concepts, the station would later form the basis of an ultra-high-resolution, spin-echo spectrometer.

Apart from expanding the HFBR's subthermal capability, the Laboratory also proposes to improve and expand its facilities for research with thermal neutrons. Four of the existing thermal beam plugs (now used to bring out five beams) would be replaced with plugs designed not only to bring out two additional thermal beams, but to make all of the beams as large as possible. One of the new beams would be used to supply neutrons to a high-resolution, triple-axis, backscattering spectrometer; the other will be reserved for future expansion. Four of the remaining five beams will serve existing instruments: three triple-axis spectrometers and one diffractometer - all rebuilt to take maximum advantage of the increased beam size. The remaining beam will provide neutrons to a new, single-crystal diffractometer using a novel multiwire area detector to increase the efficiency in data collection by an order of magnitude.

All of the above-mentioned new and rebuilt neutron instruments would be located on the reactor experimental floor inside the existing confinement building. Changes in instrumentation would be made serially, unit-by-unit to minimize interruptions to on-going programs.

In addition to providing facilities for neutron investigations, the HFBR also supplies irradiated copper positron sources for a positron beam facility. This project will add a new electrostatically focussed positron beamline containing brightness enhancing remoderation chambers. The intensity of this facility will be four orders of magnitude higher than other existing facilities in the world.

"User Fees" at Facilities
A Serious Threat to Technology Transfer

Congress has mandated a study of the feasibility of charging fees for the use of major DOE facilities. There is also some sentiment in the DOE for such charges, in the hope that the funds collected will alleviate budget problems. I believe strongly that such fees would be counterproductive in that they would discourage industrial use of the facilities and would not produce much revenue. The arguments over fees go back to the establishment of the present policy in 1979, which was driven by the construction of the National Synchrotron Light Source at Brookhaven. The facilities were constructed because the research to be carried out at them was of direct programmatic interest to the DOE. For the first time there was appreciable possible utilization of these facilities by industrial researchers carrying out basic research. Industrial scientists played critical roles in justifying the national need and in setting operating parameters of the machine. The industrial laboratories proposed to contribute significant funding to the construction of instrumentation at the NSLS, but they were unwilling to do so without a policy which gave them some control over their future costs. At the same time, there were some industrial researchers who saw significant potential benefit from such facilities, but who could not convince their management that this was a good investment since it involved a long-term view that competed with other possible short-term benefits. The advantage of open access to a major new facility helped win the day. Extensive discussions between DOE officials, Brookhaven management, representatives of other national laboratories and users from industry and universities led to the adoption of the present policy which, while it requires service and contributions of various types from users, does not call for an explicit contribution for the operation of the facility.

I summarize below some of these considerations, both policy and practical. Changing the policy now will have the detrimental effect of having induced a large investment by users in equipment and personnel at the facilities and then turning about to require contributions which might not be possible under present budgets. The credibility of the government will clearly suffer in the process. In addition, the DOE is building new facilities (the Advanced Photon Source at Argonne, the Advanced Light Source at Lawrence Berkeley Laboratory and the Advanced Neutron Source at Oak Ridge) whose justification rests to some degree on the benefits to U.S. industry of the basic and applied research that can be accomplished at them. The charging of fees will vitiate that argument by discouraging industrial participation and make operation of these devices more

difficult.

1. There are strong arguments against charging user fees to scientists from universities or non-profit organizations who carry out basic research at DOE user facilities. This is primarily because funding for such research comes predominantly from the government (either from DOE itself or from NSF, NIH or DOD). The effect of charging fees would be to establish a costly bureaucracy to transfer funds from one agency to another.

   The argument has been made that such funds should go directly to the users so that they would have the option of spending the money as they wished, in effect allowing the "marketplace" to decide whether research should be done at the facilities or at some other location or in some other manner. This point has been largely discredited because the facilities have already been built and experimental equipment installed at considerable expense to the government, at the explicit request of the user community.

2. The argument becomes more heated when the question of charges to industrial users arises. (We are talking here of charges for research whose results will be made available to all - there is agreement that proprietary research should be assessed a fee.) Here the government policy towards research by industry must be considered. It is clearly in the DOE interest to encourage industrial participation in long-term basic research. Most industrial research laboratories would not take part in such research without considerable inducement, since they take a relatively short-range approach to the type of research they support. The government spends a lot of money to have basic research performed. This takes the form of grants and contracts at universities, national laboratories and not-for-profits. By not charging fees to industrial users, the government is leveraging its funds for facility operation by the amount of expenditure by industry for staff and support salaries and for experimental equipment. In addition, the government by doing this encourages technology transfer, a prime policy objective, and it does not discriminate against users on the basis of their place of employment.

   It has always been argued that industry benefits from carrying out such research, so that it should bear the costs. Industry also benefits from the research carried out by university and national laboratory scientists. The fact is that the country benefits from the totality of the new knowledge obtained, and the country should do everything possible to increase the output and encourage collabora

tion between all scientists. This argument also overlooks the industrial funds that go into instrumentation and user services provided by the industry scientists.

3. At Brookhaven, the "Participating Research Team" mode of operation has provided benefits that both encourage such research and provide for funding benefits to the government. In this system a group of users applies for and based on a reviewed proposal, receives permission to place experimental equipment for a three-year period at the facility. No direct user fee is charged, but in return the group agrees to make 25% of the experimental time available to general users who apply. The government is then benefitting because the equipment is built and paid for by the PRT, and general users are provided with this equipment and with help in using it. At the National Synchrotron Light Source, the total cost of the two phases of construction was about $50 million. Users have provided about $120 million in instrumentation, $40 million of which is from industrial sources, so that the industrial contribution to the facility for equipment alone has nearly matched the cost of construction.

   The development of x-ray lithography at NSLS by an IBM group, referred to above, illustrates the importance of such research to the country and also the negative impact an additional fee for operations would cause. The lithography equipment, costing about $5 million, has been used for basic research not only by IBM scientists, but also by faculty and students from Cornell and RPI, among others, so that industrial contributions to education should also be counted. IBM scientists have stated that had it been necessary to pay user fees for operation of the facility, they would not have undertaken the research, and the government would have lost for the U.S. a strong position in a technology that is being vigorously supported in Japan.

4. The net effect of charging user fees for operating costs will be to discourage industrial participation in basic research, to establish a cumbersome and costly process if it is applied to university researchers and to lose for the DOE the experimental equipment, the intellectual resources and the educational benefits that would come from research on problems of programmatic interest to DOE.

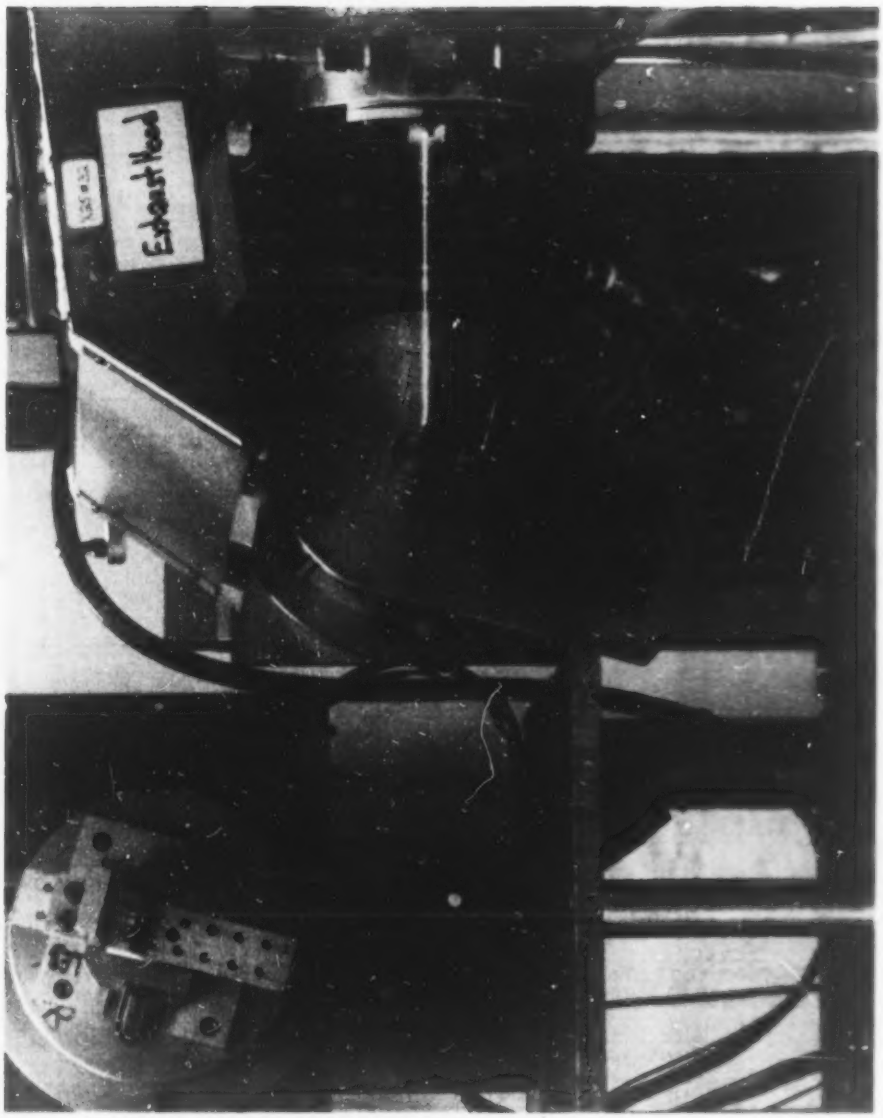
Thank you very much for considering these views.

Figure Captions

Figure 1. The high power density of the x-ray beam from a wiggler magnet at NSLS produces a blue streak of ionized air.

Figure 2. Transvenous synchrotron radiation coronary angiogram of a volunteer human patient taken on the NSLS X17B2 beamline. Patient experienced severe stenosis of the mid-portion of the right coronary artery (RCA). Balloon angioplasty was successfully performed in 1987 to reopen the RCA. The above coronary artery x-ray image of the same patient was taken at the NSLS in the Fall of 1990 and shows that the mid-portion of the RCA (see arrow) is still open.

Figure 3. The prototype compact synchrotron radiation source for x-ray lithography at Brookhaven.



REDUCED 4 SQUARE HALFTONES

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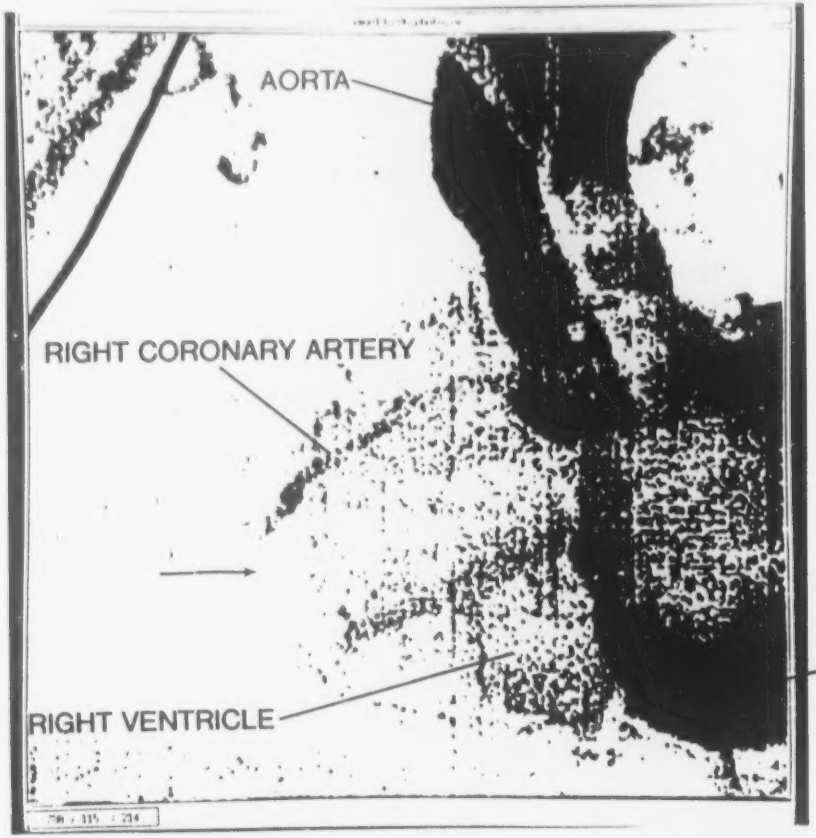
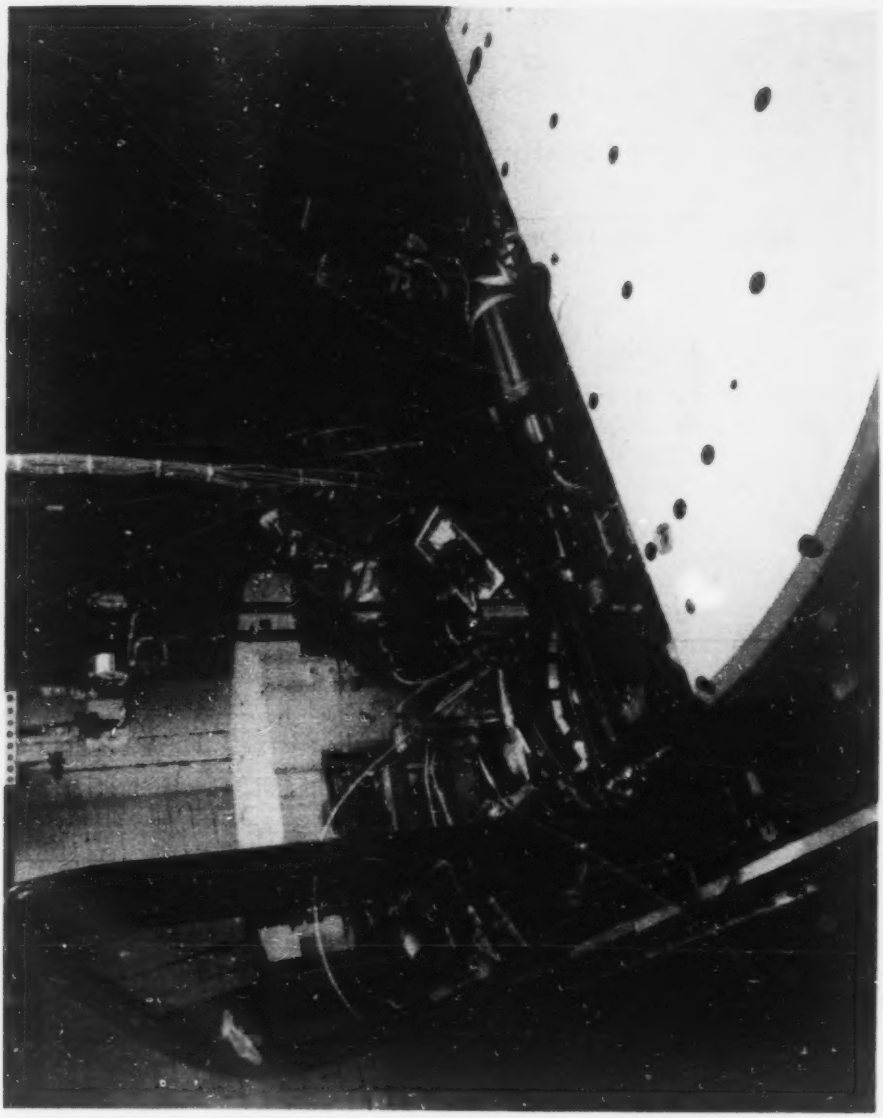


NSLS: OCTOBER 5, 1990



Biographical Data

Martin Blume is Deputy Director of Brookhaven National Laboratory, Upton, NY. He recieved his bachelor's degree from Princeton and his Ph.D. in theoretical physics from Harvard. He has been at Brookhaven since 1962 and was appointed Deputy Director in 1984. He received the E.O. Lawrence Award for Physics in 1981 for his research in theoretical solid state physics.

Mrs. LLOYD. Thank you very much.
Dr. Knotek.

STATEMENT OF DR. MICHAEL L. KNOTEK, SENIOR SCIENCE DIRECTOR, PACIFIC NORTHWEST LABORATORY

Dr. KNOTEK. Thank you very much. Madame Chairwoman and members of the committee, it is a real pleasure to be here today on behalf of the Pacific Northwest Laboratories to speak to you about materials science efforts within the DOE.

We at Pacific Northwest Labs have a primary mission of developing technology for many segments of the Nation's needs. We really regard materials science as the great enabler. Enormous strides have been made in our ability to measure and understand the control of materials properties and that has led to our ability to develop materials for a wide range of applications.

In materials science, solid state physics, chemistry, biology, geology and many other disciplines come together. These go together to help us both create new materials and to better understand Nature's own materials.

The underlying part of this, of course, is our ability to understand the structure function relationship in materials. PNL has by far its major activity in the area of environmental work, and that is what I wanted to stress here today. We are very much involved in the environmental restoration of waste management activities at the Department of Energy, but we are also involved in commercial activities and in the energy sector, in global climate change and in the National infrastructure.

In all of those, the Nation is coming to grips with the fact that our materials, our materials usage, our materials processing and the disposal of materials are all on a collision course with nature. We have created really large insults to the environment. Many of those must be remedied in the very near future.

In addition, we need to find a completely new set of materials and processing technologies to keep this from happening in the future. There are many pieces to this. The first of those is that we must really fully understand and characterize what we have done to the air and the soil and the water and find better ways to remove the risk to the public and to the environment.

Following that, we must develop new materials and processes, of course.

PNL is establishing a large effort in the environmental and molecular sciences laboratory, which will be aimed at understanding the chemical processes, the basic chemistry that is involved in these areas, the materials issues, the biological issues and also develop theories and models to help us better deal with these problems.

I really wanted to mention four specific areas, which are really critical and which we are focussing our efforts on and which we feel that additional support in the Material Sciences are required.

The first of these is the fact that we are having a very difficult time in analyzing things, such as at the Hanford Site where we are encountering major technical barriers in characterizing the problem that we have. Virtually all of the waste that is in our environ-

ment today is not where we would like it. It is in a very, very complicated state, and we do not have the technology to deal with that—to understand where it is, what it is doing, where it is going and how it could get into the environment and to humans.

It is also highly mixed. What that means is we have a mix of a variety of wastes varying from extremely dangerous things, such as technicium in which case waste must be stored for thousands of years and is very, very complex to deal with, all the way to things that relatively benign. But they are all mixed together in a very untoward way.

We must develop technologies to reseparate those, so we can deal with them each as their own danger would suggest. We must better learn how to encapsulate these wastes once we get them separated. Encapsulation means forever removing the risk to the public by taking them out of the biocycle. We have found that that is an extremely difficult task and different materials must be developed for each individual type of radiologic or chemical contaminant.

Finally, we must find much better ways to predict how these things behave in the environment, how they are transported through the environment, and how we can better deal with them in place.

Since they are in such large quantities, we must be able to go into the ground, detect them in place, treat them in place and keep them in place, but still assure the public that they are risk free. All of these things will require large efforts in the material science community. We feel that at this point the incremental effort within the community is not commensurate with the Nation's commitment to clean up these problems.

Thank you.

[The prepared statement of Dr. Knotek follows:]

Testimony of

DR. MICHAEL L. KNOTEK

Senior Science Director

Pacific Northwest Laboratory

Before the

Committee on Science, Space, and Technology

Subcommittee on Energy

United States House of Representatives

Washington, D.C.

March 19, 1991

42-234 0 - 91 - 5

Madam Chairman and Members of the Subcommittee, it is a pleasure to be here today on behalf of the Pacific Northwest Laboratory, which is managed for the Department of Energy by Battelle Memorial Institute. Your invitation to testify asked that I provide my views on the importance of materials science as it relates to national needs and the missions of the Department of Energy.

I believe it would be impossible for me to overstate the importance of the role materials science now plays, and will continue to play, in meeting the needs of our nation and fulfilling the missions of the Department of Energy. The connection is simple. Our society, our quality of life, and our economic development depend on technology, and the development of technology depends on materials.

Background

As pointed out in the 1989 National Research Council report, Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Age of Materials, "Without new materials and their efficient production, our world of modern devices, machines, computers, automobiles, aircraft, communication equipment, and structural products could not exist." This observation is echoed in the recent Materials Research Society publication, A National Agenda for Materials Sciences and Engineering: Implementing the MS&E Report, which states, "Virtually all new technologies are driven by advances in materials, and the future competitiveness of the U.S. depends on our relative ability to adapt these new technologies to the needs of our society."

Both the National Research Council report and the Materials Society publication note that while support for materials science and engineering in other countries has increased, U.S. federal nondefense and industry support for materials research and development, particularly long-range research, has declined. To remedy this situation, the Council report recommended a national program, including strong efforts in the four basic elements of materials science and engineering; synthesis and processing; structure and composition;

properties; and performance. The Pacific Northwest Laboratory strongly agrees with this recommendation.

The Department of Energy and its predecessor agencies have had a longstanding role in materials research in the United States. Starting with the Manhattan Project and continuing with AEC and ERDA, the evolution of several laboratories, including new scientific facilities, can be traced directly to this support for materials research. The Department can be proud of its accomplishments in the development of new materials and processes. However, as the aforementioned reports pointed out, many opportunities that relate to materials are not being exploited by the DOE and other federal agencies. Much needs to be done for a variety of important applications.

Materials Research Needs and Environmental Challenges

One of the most important contributions materials science programs funded by the Department of Energy can make is to provide the tools and techniques we need to restore the environment and clean up hazardous, toxic, and radioactive wastes. The Department has published its Five-Year Plan for Environmental Restoration/Waste Management, and identified the problems at each of its sites. The Department has also separately identified the research needs to develop innovative new technologies for environmental remediation.

Few aspects of environmental restoration can be reasonably and economically accomplished without advances in materials science. Simply stated, we need new materials that can serve as sensors to detect and monitor subsurface contaminants or characterize the components of mixed waste; new membrane and ion exchange materials to assist waste treatment and separation; and new and well-understood containment and barrier materials to immobilize and stabilize waste over very long periods of time.

These environmentally related problems have pushed materials science into new areas that require detailed, molecular-level understanding of very complex systems. For example, it is much easier to design a sensor to detect the presence of a contaminant during the processing of a semiconductor chip in

a well-controlled environment than it is to develop a sensor to detect a similar contaminant groundwater system where we have little direct control.

Similarly, to create verifiable models that can accurately predict the lifetime of barrier and containment materials, we must have a detailed mechanistic understanding of the interactions of a material with its environment. Environmentally related materials science may appear less glamorous than the creation of a new high-temperature superconductor, but the long-term impact on our society and quality of life may be much greater.

The Department has begun to address these questions in a focused matter through the Basic Energy Sciences budget. Funds have been included for research support and capital equipment to create a Molecular Science Research Center at the Pacific Northwest Laboratory. The Materials and Interfaces Research Program, which is a key component of the Molecular Sciences Research Center at PNL, is aimed at understanding these problems.

This research program is generating the information we need to design and synthesize advanced materials to analyze and separate mixed chemical and hazardous wastes, to provide long-term storage of hazardous materials, and to develop chemical sensors for environmental monitoring of various organic and inorganic species. The program includes provisions for supporting facilities that will enable scientists to synthesize new materials, as well as advanced instrumentation to study their structural, mechanical, electronic, and chemical properties.

In September 1990, PNL hosted a workshop to explore materials and interfaces research needs related to environmental concerns. The workshop was attended by more than 50 scientists representing materials science, physics, surface and interface science, chemistry, chemical engineering, and earth and environmental sciences. About half the participants were from PNL; the remainder were from national laboratories, universities, and research organizations throughout the United States. The workshop identified four major challenges or issues related to environmental cleanup, waste storage,

and restoration that are directly dependent on materials science--both basic and applied.

1. **We must be able to detect and characterize hazardous waste.** Detection and characterization require, among other things, the development of selective sensors that function in complex environments.

2. **We must minimize the amount of waste that must be treated as hazardous, so we can reduce cleanup costs an disposal volume.** Waste minimization requires the development of separations membranes, ion exchange or selective sorption materials, and catalysts for waste destruction.

3. **We must encapsulate hazardous waste for permanent disposal.** Effective containment requires materials that have low and predictable reaction rates with their environment; are stable to radiation effects; and are compatible with each other if multiple containment is required. To ensure that containment materials possess these properties, we must expand our fundamental understanding of phase stability and alteration and reaction mechanisms.

4. **We must be able to predict the transport of hazardous waste from contaminated areas as well as potential disposal sites.** To ensure accurate predictions, models must account for many factors, including sorption and/or desorption on mineral surfaces and colloid formation and transport. These models can only be developed through molecular-level research of mineral surface interactions with various hazardous waste constituents and with colloids as well as stability fields for colloids.

Based on these materials science challenges and issues, the workshop participants identified three important research areas that DOE should address: interface structure and chemistry, materials and interface stability, and materials synthesis. The **interface structure and chemistry** research area includes two related, but somewhat distinct, objectives. One is to expand our knowledge of the surface structure and chemistry of oxides, minerals, clays, and other environmentally relevant materials with the ultimate goal of achieving a level of understanding that equals current

knowledge of metals and semiconductors. The other is to develop more detailed information about what happens at solid-liquid interfaces and how various contaminants affect interface properties.

Many of the basic interface structure and chemistry studies will involve idealized model systems; however, the ultimate success of this research effort will depend upon the relationship between the idealized models and real-world systems, which generally are much more complex. For example, the program must include examinations of typical complications introduced by the addition of components to the system under study as well as studies of real materials in relation to the model systems.

Two examples of technologies that must rely on an understanding of materials and interface stability are waste containment barriers and advanced sensors for remote operation in hostile environments. Containment and barrier materials may alter with time as a result of radiation, thermal gradients, or reactions with the environment. We must be able to predict such alterations and potential changes in material properties. Furthermore, sensors may involve integrated circuit-based technology that is unsuitable for operation in harsh, complex environments.

Research in this area must address the stability of composite materials designed to have specific optical, electronic, or chemical properties and the interfaces and reaction layers that form as a result of environmental interactions. Studies should range from the examination of simplified model interfaces to real-time, in-situ characterization of buried interfaces.

The materials synthesis research effort must involve the creation of model surfaces and interfaces for detailed examination as well as the formation or synthesis of new materials with specific properties. We need model surfaces and interfaces to improve our molecular-level understanding of the surface structure and chemistry of environmentally relevant materials such as oxides, clays, and minerals. These models will enable researchers to compare theoretical calculations with experimental measurements, which can be obtained most readily from well-characterized, often single-crystal, surfaces.

We also need materials with new or improved properties because some environmentally related requirements cannot be met easily by existing materials. This is especially true in the containment areas as well as some sensor areas. Natural hard tissue materials are of special interest because they develop unusual properties from rather normal starting materials. Biomimetric systems that imitate nature offer the potential for protective ceramic coatings and unique sensor properties as well as the formation of natural ceramic materials within the geologic environment to serve as stable barriers or containment materials for hazardous waste.

The Environmental and Molecular Sciences Laboratory

The materials science programs conducted by DOE will be substantially upgraded when several new scientific facilities are completed. The Advanced Photon Source at Lawrence Berkeley Laboratory, the Advanced Light Source at Argonne National Laboratory, the Advanced Neutron Source at Oak Ridge National Laboratory, and the Environmental and Molecular Sciences Laboratory at the Pacific Northwest Laboratory will provide researchers throughout the United States with new and unique capabilities for materials research.

The Environmental and Molecular Sciences Laboratory will provide one-of-a-kind capabilities to researchers for materials research for a variety of applications relating to environmental restoration. EMSL will be a focal point for molecular-level research in the United States, and will provide industry with the information to accelerate the development of cost-effective technologies for environmental remediation challenges facing DOE, other federal agencies, and the private sector. (Attached to my testimony is project summary which provides more detail on EMSL.)

One of the reviews conducted on the EMSL proposal characterized the materials science challenges associated with environmental restoration and the role of EMSL as follows: "The intellectual challenge of the EMSL's mission is staggering, however the practical payoff of success in this mission is immense on the level of, or perhaps beyond, that of the Manhattan Project."

Summary

Materials science has given us new metals, ceramics, and composites with extraordinary properties designed for specific applications. Materials science has produced innovative concepts that enable us to improve and tailor existing materials to meet new or unique requirements. And, materials science has provided benefits and applications that affect every aspect of our society and economy.

Materials science also has the potential for making vital contributions to the solution of environmental restoration and waste management problems faced by the DOE and the nation. The four challenges described here are universal. The task of surmounting these challenges is formidable but not beyond our capabilities, providing we establish clear targets and empower the scientific community to achieve them. Despite today's constrained budgets, the long-term payoff from an enhanced materials science program should be substantial. I urge the Committee to weigh that option.

User Fees at DOE/BES User Facilities

I thought it appropriate, given my past experience as Chairman of the National Synchrotron Light Source, to comment on the charging of User Fees at the DOE/BEST user facilities. The ground rules at these facilities are that all capabilities are available to the entire community of scientists--be they from academia, industry, or the government's own institutions.

It is important, however, to realize that a typical "experiment" contains elements from many sources, all contributed for the common welfare of the community of users and stationed permanently at the facility. While the core instrument, such as the reactor or synchrotron, is provided by the DOE, the actual experimental apparatus that makes the experiment a reality will contain elements of capital equipment, technical support manpower, operating systems, supporting experiments away from the facility, and data analysis and administrative support from a large number of institutions bridging every possible funding and disciplinary boundary.

The concept of "ownership" of such capability is not at all clear. Since each user now provides its "in-kind" support gratis to the community, this entire concept will have to be revised if the DOE seeks cost recovery for its part. Indeed, this whole phenomenon of interinstitutional support and collaboration, which has been one of the great successes to come out of the National User Facility concept, could be damaged if we do not carefully weigh the value of material and intellectual contributions from all sources in establishing support policy.

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ENVIRONMENTAL AND MOLECULAR SCIENCES LABORATORY

Project Summary

NEEDS AND GOALS

The United States has embarked on an environmental restoration effort that dwarfs any scientific enterprise this country has ever launched. Estimated cost for cleanup of Department of Energy production sites alone is equivalent to a number of superconducting supercolliders, several space stations, or another trip to the moon. The unresolved scientific problems of this effort are as complex as any this nation has ever faced, yet they are critical to our quality of life and economic competitiveness. Research and innovation are the only ways to assure restoration and protection of our environment by reducing cost, uncertainty, and risk.

The Environmental and Molecular Sciences Laboratory (EMSL) will capitalize on today's revolution in experimental and theoretical molecular sciences to meet DOE's environmental commitments and to create a science base for other DOE and national needs. Its research will be multidisciplinary, spanning physics, chemistry, materials science, biology, geology, hydrology, mathematics, computer science, and the environmental sciences. Worldwide there is no adequate model for the effort required. DOE needs a project scaled to encompass critical masses in all necessary fields and a programmatic setting containing practical problems that focus the research.

To meet DOE's need, the EMSL will have as its cornerstones:

fundamental research in underlying chemical, materials, biological, computational, and environmental sciences.

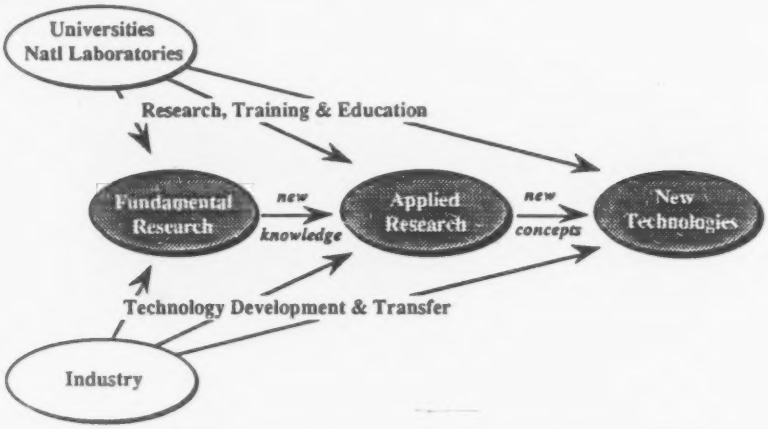
applied research that focuses fundamental knowledge on specific problems.

research, education, and training opportunities for the entire scientific and technical community, which will use the facility.

rapid transfer of technology by involvement of industry.

PROGRAMS AND FACILITIES OF THE EMSL

The EMSL project will develop the requisite interdisciplinary research programs, forefront research equipment, and supporting facilities to meet these demanding



EMSL Focuses Multisite Collaborations on Research and Technology Needs in Environmental Restoration and Waste Management

scientific challenges posed by DOE's environmental initiative. The EMSL will house 300 core and visiting scientists with world-class instrumentation and computational resources in a 200,000 square foot facility. The $220-million investment includes design and development costs for beyond state-of-the-art instrumentation; construction of the building; acquisition, installation and commissioning of the instrumentation; initial operations; and all associated management costs. When complete the EMSL's annual research programs and operations budget will be roughly $60 million.

Research supported by the Offices of Environmental Management (EM) and Energy Research (ER) is organized into six programs.

The **Chemical Structure & Dynamics** program will study chemical kinetics and reaction dynamics of terrestrial and atmospheric processes and the chemistry of complex waste forms and waste storage media using new laser systems, new surface mapping techniques, and molecular clusters that mimic adsorbate/surface interactions. The program will generate new knowledge for geochemical modeling of contaminated soils, for understanding the behavior of wastes in interim storage, for developing novel approaches to remediation, and for evaluating proposed treatment methods.

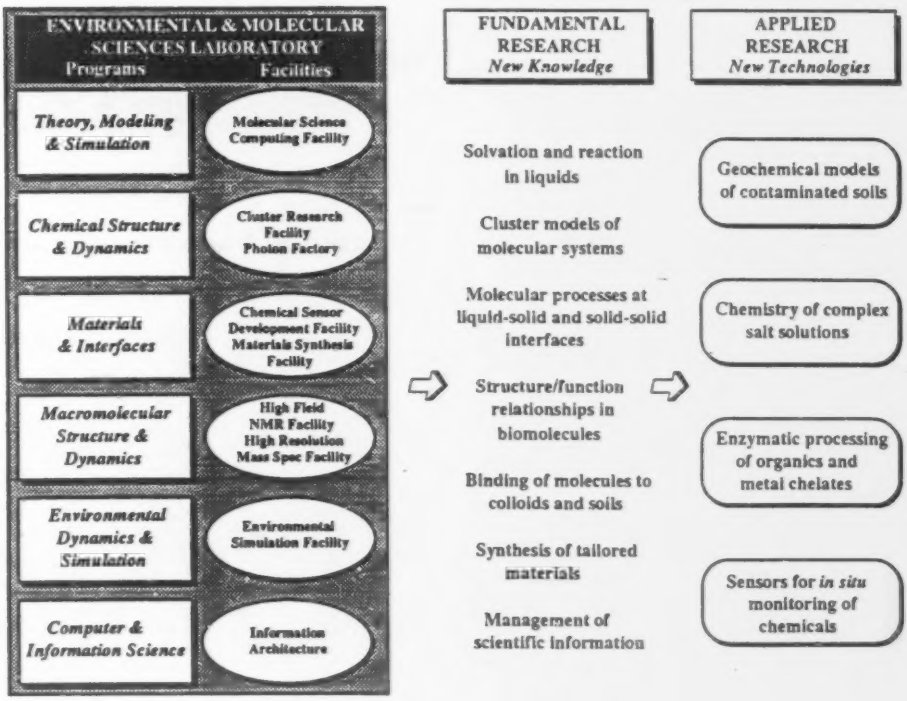
The **Environmental Dynamics & Simulation** program will establish a molecular-level understanding of the bonding forces and speciation of chemicals in colloidal suspensions and of chemicals sorbed on soils. A multidisciplinary approach will use controlled environmental chambers that simulate real-world conditions. New experimental results and theoretical analyses will provide

detailed descriptions of chemical reactions in complex mixtures and at solid-liquid interfaces. Resulting models will predict the fate and transport of contaminant species and provide a scientific basis for remediation schemes.

The **Macromolecular Structure & Dynamics** program will determine biomolecular structure/function relationships for processes that control the biological transformation of contaminants and the health effects of toxic substances. The world's first 1000-megahertz nuclear magnetic resonance (NMR) system and advanced mass spectrometers will be used for structural analysis of key enzymes and genetic material to enhance the use of natural systems for bioremediation, to guide the rational design of new systems having specific activity, and to establish a molecular basis for health risk assessment.

The **Theory, Modeling & Simulation** program will develop detailed molecular level descriptions of the chemical, physical, and biological processes in natural and contaminated systems. This research will use the full spectrum of computational techniques and one of the world's most powerful computer

EMSL Programs, Facilities and Research Activities



systems to model chemical and physical properties of wastes and contaminant interaction with soils and groundwater. This program will produce knowledge needed to predict waste form behavior, suggest new remediation strategies, and support predictions of long-term consequences of proposed ER/WM activities.

The **Materials and Interfaces** program will generate information to support the design and synthesis of advanced materials for the analysis and separation of mixed chemical waste, the long-term storage of concentrated hazardous materials, and the development of chemical sensors for environmental monitoring of a wide variety of organic and inorganic species. Supporting this program will be facilities to synthesize novel materials and instrumentation to study their structural, mechanical, electronic, and chemical properties.

The **Computer & Information Sciences** program will develop new approaches to handle vast amounts of data and perform calculations for complex natural systems. The EMSL will contain a high-performance computing facility and ancillary computing laboratories, as well as high-speed data acquisition systems for all of the major research instruments. An information system will be developed to speed communications of fundamental research results to applications areas.

The EMSL will be a **Collaborative Research Facility**. It will attract hundreds of academic, industrial, and government scientists and students each year. These visitors will collaborate with the in-house staff to develop new levels of understanding and permanent solutions to the nation's environmental problems. **Education and training** programs will motivate external collaborators to continue this research at their home institutions. **Technology transfer** will be achieved by involving industrial and academic partners in the development of frontier research capabilities and the integration of new knowledge and concepts into critical technologies.

Mrs. LLOYD. Thank you, Dr. Knotek.

Mr. Morrison.

Mr. MORRISON. Thank you.

Dr. Knotek, I asked Jim Decker the question that related to the National Energy Strategy. It very clearly identifies a need to understand the materials related to waste management issues. Of course, we are very proud of the environmental and molecular sciences laboratory that is the effort that you are heading. I know you are focussing in this area that relates to hazardous and radioactive waste.

Could you, for the record, share with us your immediate needs as it relates to funding for this important materials effort related to the environment?

Dr. KNOTEK. As you know, at this point, we have money in this year's budget to deal with design of our facility and get it moving. We have base funding to get our program moving.

I think our goal is the fact that when this facility is ready to go in 1995, we must have the programs in place to adequately occupy and carry out the programs within it. What that means is that over the next five years, we must go from our present support level of $6 million to $10 million up to something like $25 million or so.

At this point, the Secretary of Energy helped us by providing additional funds this year. If those materialize as we think they will, we will be in fairly decent shape this year. But next year, we will need an extra increment of dollars to stay on track.

Mr. MORRISON. How does this funding schedule relate to the drivers at, say, a facility like Hanford where we have a tripartite agreement with the State and EPA and the five-year plan submitted by the Secretary? Are you going to be able to provide the materials and the technologies to do that job in time?

Dr. KNOTEK. I think we are certainly going to make every effort. We wouldn't be heading off in that direction if we didn't think we could. At this time, if we could stay on the present track, we hope to be able to have the full program functioning, as I said, within the next three years. We have already got roughly one-quarter of the full program running at interim facilities. We are already making contributions. But I think we must stay on top of this and the funding must continue to increase, so we can get these programs in place in time.

Mr. MORRISON. Is it fair to assume that the faster we can get your laboratory in operation, that the greater the probability we will be able to save funds and effectively complete the cleanup?

Dr. KNOTEK. Absolutely. There is no question about that. There is a great need for much more research in the chemistry, materials and biological aspects of this problem. The quicker it can be put in place, the better. It also allows to more diligently and thoroughly involve the rest of the scientific community in this problem. They need a place where they can come and be exposed to these problems and help us work on them.

Mr. MORRISON. It almost appears to me that this clean-up project may rival the Manhattan project as far as the pressures it puts on us as a Nation.

Dr. KNOTEK. If you think about it, it is the anti-Manhattan project because it is cleaning up the entire accumulated waste for

the entire 40-year production that is still out there to be dealt with. None of it is where we would like it to be.

Mr. MORRISON. I am confident you can provide an answer.

Thank you, Madame Chairwoman.

Mrs. LLOYD. Thank you, Mr. Morrison.

Mr. Fawell.

Mr. FAWELL. Thank you, Madame Chairwoman.

This may be more of a comment, but partially a question. Dr. Blume, in your statement, you stated that the funds have been redirected to other projects which have in many cases little relation to materials science and Basic Energy Sciences. I was referring with Dr. Decker to the fact that there was this blip upwards in the funding of Material Sciences in 1991 to 274 and then downward to 257 this year.

Am I right in assuming that we have perhaps non-peer reviewed additions in the conference committee kinds of things? Is that what happened last year in this area?

Mr. BLUME. Yes. That is what I was referring to.

Mr. FAWELL. That is unfortunate because I think we are all aware of the importance of funding in this area. The Authorization Committee does its best to peer review and struggle and work with this. Then we see at the last minute some of it goes up in smoke when we have these things occur. Maybe we can just be that much more alert this year in reference to that.

At least, I guess, the caps are a little bit higher, Madame Chairwoman, as a result. So that is a blessing.

Thank you very much for your testimony.

Dr. BLUME. If I might just comment on that. I do understand the fact that there are going to be projects that are of importance that do enter the budget this way. The only thing that I would ask is that it not get confused with the Materials Research budget, because there are separate priorities that exist there. Unfortunately, this is what appears to have happened. These projects come in and are funded at the expense of the Materials Research.

Mr. FAWELL. Yes. I think Dr. Fradin would verify that personnel had to be laid off at Argonne last year as a result of this, wasn't it?

Dr. FRADIN. There has been attrition in the last few years. We have tightened the belt as much as possible on the non-salary related activities. Now I really believe that salaries and so forth make up about 85 percent of the cost of doing business in research. There is no other alternative, other than to reduce employment to take PhD long-term scientists out of the program.

Mr. FAWELL. Well, let us hope we will be eagle-eyed and be watching the appropriation process that much closer.

Thank you very much. I appreciate the testimony.

Mrs. LLOYD. Thank you, Mr. Fawell.

Dr. Blume, as you know, we had to have an increase in user facility, and that will soon be in operation. As we see the growth in this program, how are we going to maintain the current balance between our base program and the user facilities operation? Is this going to erode our base program?

Dr. BLUME. It certainly will erode the base program. We are going to have to look in the long term, undoubtedly, at closing some of our facilities. It is unrealistic to expect that we'll continue

working them. Certainly we expect that when the Advanced Neutron Source is operational at Oak Ridge, that there will be a consideration to shutting down the High Flux Beam Reactor and the High Flux Isotope Reactor. That would be very logical to concentrate our neutron scattering efforts at the forefront facility that exists at that time.

Beyond that, it is going to be very difficult for us to re-establish the balance that we had earlier if we take the present facilities that we have in the pipeline and the currently operating forefront one. It is going to take a fairly delicate dance for us to be able to do this. Sometimes dancing will not be a substitute for additional funds.

Mrs. LLOYD. You mentioned that you felt that user fees were a threat to technology transfer. It didn't seem to me that we have had a tremendous amount of user fees come in, have we?

Dr. BLUME. No. We have had very little in the way of user fees. I believe the hope, however, is to enhance the amount of money coming in. The phrase that I have used elsewhere is that there may be a pot of gold at the end of the light source rainbow that we have.

It is not the case. The amount of money that is likely to be raised is very small. If we charged users now for the experiments that they carry out that are basic research——

Mrs. LLOYD. You are speaking of generic research.

Dr. BLUME. Generic research, yes. Research that users agree to make public immediately, that they publish in the open literature. We have to remember that users are bringing quite a lot to these facilities. They bring very much in the way of in-kind support that amounts to a very sizable contribution.

As an example, at the Synchrotron Light Source, the outside users have provided about $120 million in equipment as compared to the cost of building the facility at $50 million. Of that $120 million—much of that is Government funding, of course. The university money is almost entirely Government funding. But $40 million of that has come from industry. This provides facilities that would not have otherwise been available.

Most of the industrial scientists that we have questioned have said that if they had to pay for the operation of the facility, they would not have been able to convince their management to embark on this in the first place. It is this loss that would be a very serious blow to technology.

Mrs. LLOYD. Of course, we have to realize, as Dr. Fradin mentioned, that we have to look out for economic security. At the same time, our technology transfer is our means of enhancing the wealth of our Nation, which in turn, pays through tax dollars for the Federal investment in your laboratories. This is, we hope, to create new wealth to enhance your capability as well.

Dr. Knotek, it seems to me that the potential for materials developed by molecular science appears to be almost limitless.

How far are we coming up? Are we holding our own? How are we in our standing with other countries in this field?

Dr. KNOTEK. I would say we have certainly come a long way. Much of the progress is due to some of the major facilities we do

have already. The ability to better understand these materials has led to the advantage.

Mrs. LLOYD. And how involved is industry?

Dr. KNOTEK. Industry is very involved. For example, the Light Source as an example I know best, having been there, roughly 40 percent of the capital plant was provided by industry. They had, I would guess, between 30 and 50 people permanently residing at the facility. They were as large a factor in the development and the implementation of that facility as was the Federal Government as far as intellectual part of the activity.

I would say if you look at how materials science is being exploited in other areas, such as in Japan and even in Europe, they are being very aggressive. Part of their enhanced economic competitiveness is their ability to attack materials science on a very broad front and bring it to bear on their problems. We simply have to do a little more in that area, I think.

Mrs. LLOYD. Dr. Fradin, you mentioned that the Academy has recommended our Materials budget be increased by 40 percent. Would this increase provide additional funds for key user facilities? It seems this is a very invaluable tool for materials research.

Dr. FRADIN. I am sure some of it would go in that direction through industrial involvement and university involvement at the facilities. But I think the Material Science and Engineering study really focused on a number of materials issues that affect particular technological areas, particular industry, such as communications, such as structural materials for automotive, air frame, et cetera, optical electronics and so forth.

These particular areas are areas where there is very heated competition with European and Japanese competitors. There are some areas where we have, in fact, fallen fairly far behind. Structural ceramics is one. Another area is organic conductors where the Japanese are really out-distancing us. This really has a lot to do with the fact that in the non- defense related areas, we have not been making the investment that our counterparts in Europe and Japan have been making, both from the Federal monies, as well as from the industrial monies.

So there is an opportunity here, as Dr. Bromley has said recently, for the Nation to recapture its lead in materials research. Really, this is what I think has been called for in the Materials Science and Engineering study in the implementation report.

Mrs. LLOYD. We certainly thank you for your contributions, not only at the hearing today but what you do for our country. Thank you for being with us today.

Our last panel consists of three witnesses: Dr. Jay Marx, Director of the Advanced Light Source at the Lawrence Berkeley Laboratory; Dr. David Moncton, Associate Laboratory Director of the Advanced Photon Source at the Argonne National Laboratory; and Dr. B.R. Appleton, who is Associate Director for Physical Sciences and Advanced Materials at Oak Ridge National Laboratory.

Thank you for joining us today. Happy to have you with us again. Good to see you here.

Dr. Marx, if you would begin.

STATEMENT OF DR. JAY N. MARX, DIRECTOR, ADVANCED LIGHT SOURCE, LAWRENCE BERKELEY LABORATORY

Dr. MARX. Thank you, Madame Chairwoman, members of the committee. I am pleased to be here today to tell you about the Advanced Light Source, a new research facility now under construction at the Lawrence Berkeley Laboratory.

The Advanced Light Source or the ALS is the next generation radiation optimized to use magnetic devices called undulators and wigglers in a large electron storage ring. These devices generate beams of ultraviolet and soft X-ray radiation of unprecedented brightness with many of the desirable features found now in lasers.

This facility will serve the Nation's scientific and technical community from both the public and the private sectors when operations begin in April of 1993. At that time, the ALS will be the most advanced synchrotron of its type for forefront research and biology, chemistry and material science and technology development, including aspects of X-ray lithography.

Over 200 scientists from industry, academia and the National Labs are already planning their research at the ALS, while hundreds of others have indicated future interest in utilizing the world leading capabilities planned at the ALS.

Let me say at the outset that the ALS is on schedule with the construction project targeted for completion in April of 1993 and we're on budget. Our total construction cost is $99.5 million. The excellent progress we have made is indicated by the fact that a few weeks ago, the 50 million volt linear accelerator, which is a major system of the ALS injector complex, operated at full energy in a test run. That important milestone was reached only two weeks after we first put accelerating power into that device.

The ALS construction project consists of the building that houses the facility, a complex of particle accelerators to provide the high energy electrons that are the source of the ultraviolet and soft X-ray light and an environmental storage ring where the electrons generate these X-rays and a small number of the 40 or so beam lines that bring these X-rays down to experimental stations.

Construction of the ALS began in fiscal year 1987. The ALS building is now within a few weeks of completion. The injector complex is installed and into the testing phase. Most of the storage ring components have been fabricated, and their installation will begin in a few months. The storage ring itself will then be ready for testing in the spring of 1992. These tests will continue for about a year.

The X-ray beam lines that are hooked onto that storage ring will be installed during the final year of the project. The initial research program at the ALS is now coming into very strong focus. Last year, we received proposals from 18 research teams for initial access to the facility. These proposals were reviewed by a program review panel representing the many disciplines that we will use at the ALS. That panel was impressed with the qualities of these initial proposals and the quality of the researchers wishing to use the ALS.

With the motivation of utilizing the world leading capabilities that the ALS will provide, those teams with approved proposals

have since been working diligently to develop the resources to support their research plans. They have been designing equipment that they will need to utilize the ALS.

We are also continuing now to receive other proposals from research teams who wish to participate. Our initial research program will tap the talents of scientists from the Nation's best research universities, the National Laboratories and the private sector.

The industrial scientists will study the properties of semi-conductors, magnetic materials and surface phenomenon. They will also pursue research in microfabrication techniques and characterization, including novel lithography methods targeted at that more powerful microchip in the next century.

Structural biology research at the ALS will use X-ray microscopes to study cell biology and diffraction techniques to unravel the structure and function of complex molecules relevant to understanding disease and to developing new pharmaceuticals. Scientists working at the ALS will also probe the structure of new materials and study complex chemical reactions that will lead to a fundamental understanding of the combustion process. This could have a significant impact on the efficient use of energy in the 21st century.

Our task of providing X-rays to these eager scientists is only the first step towards utilization of the ALS. Following the normal practice for the Department of Energy National User Facilities, our construction budget provides a basic facility without all the experimental equipment and the laboratory space needed by the visiting scientists. This approach was taken with the expectation that additional resources would be found to support the initial research program, and that the most fruitful long-range opportunities and needs would become apparent during the facilities' early years of operation.

What we are finding, however, is that the research community is already facing severe near-term funding limitations that could limit their ability to exploit the opportunities afforded by the ALS. We are now hard at work on strategies, including new initiatives for addressing these needs.

Our strategy for supporting the research program at the ALS has placed considerable responsibility on research teams to develop their own funding. With the exception of one team with a large number of participants from IBM, all of these research teams are dependent primarily on Federal agencies for support. Even the IBM team has academic members who are seeking Federal funds. While all the initial user groups have made or about to submit proposals, there is yet no firm commitment by any agency to provide funding for their research at the ALS.

As part of our overall strategy, in the areas of structural biology and combustion dynamics, ALS research teams have linked their interests to two major LBL initiatives. These are the ALS Life Sciences Center, which is part of DOE's structural biology initiative and a combustion dynamics initiative currently being evaluated by DOE's Office of Basic Energy Sciences. Each initiative funded would be operated by Lawrence Berkeley Lab as a National User Facility to provide access to the ALS and to the specialized additional facilities that would be developed.

My concern here is that unless significant support can be developed from Federal agencies and unless we can motivate substantial investment in the ALS from the private sector, we face a very limited initial research program that would not take full advantage of the exciting opportunities the ALS could provide.

Another significant concern for the ALS and for the other DOE National User Facilities is the question of user fees. Although the principle of user fees is undoubtedly valid and appropriate for some classes of Federal facilities, the great majority of users of BES facilities are supported by Federal funds. So a user fee for these facilities would result in very little additional revenue. For example, we expect more than 80 percent of ALS users to be supported in their research by Federal agencies.

In addition, non-Federal sources, primarily industry, are making significant investments to both equipment and personnel, that enhance the overall utilization of the BES facilities. This investment results in a significant increase in research and the capabilities that can be provided for researchers both from the public and the private sectors. For example, the non-Federal investment at the National Synchrotron Light Source at Brookhaven is estimated at $55 million of capital costs and yearly the operating cost of $11 million.

Imposition of new fees would severely curtail participation in these facilities by the private sector. The result would be a reduction in research productivity and collaborations between the private sector and Federally supported researchers—collaborations that are such a desirable part of these facilities.

This kind of extensive collaboration between industry, academic and national laboratory scientists is, in fact, one of the most important drivers of the high quality of research coming from these facilities.

The worst thing to do would be to put the barrier of user fees in the way of such collaborations. It would result in industry greatly curtailing or terminating such cooperative efforts, and would destroy the many advantages of these collaborations. As a result, the advantage to the Nation of a huge investment of public funds would be compromised.

I strongly recommend that no change be made in the existing policy, which has been so successful in promoting effective collaboration across the research spectrum and which has encourage large, non-Federal investments at the DOE's user facilities. It would not be in the best interest of this Nation's technical and economic health to impose the barrier of user fees. Moreover, it would run counter to the interest of Congress in encouraging increased partnerships between the public and private sectors.

In conclusion, I want to emphasize that the ALS is on schedule towards completion within budget in the spring of 1993. We have an enthusiastic user community working hard to put in place a world class research program in a broad range of basic and applied science and technology.

Thank you.

[The prepared statement of Dr. Marx follows:]

Written Statement of Jay N. Marx
Director, Advanced Light Source
Lawrence Berkeley Laboratory
before the
House Science, Space, and Technology Committee
Subcommittee on Energy
Tuesday, March 19, 1991

I am pleased to be here today to tell you about the Advanced Light Source, a new research facility now under construction at the Lawrence Berkeley Laboratory (LBL) of the University of California with a planned completion date of spring 1993. At that time, the ALS will join the ranks of the U.S. Department of Energy's national user facilities. Extremely bright beams of x-ray and ultraviolet radiation from the ALS will be available at no charge to qualified scientists from industry, from federal laboratories, and from universities. As I will explain later in more detail, the ALS complements another new facility, the Advanced Photon Source, which is being built at the Argonne National Laboratory. Equivalent facilities are also under construction or planned in both Europe and Asia. I am pleased to report that the ALS is proceeding on schedule and will be completed within budget.

At LBL, we are confident that ALS users will make contributions of great significance to our nation's storehouse of both fundamental and applied knowledge about the structure and properties of materials and matter in all its varied forms down to the atomic level. In areas such as metals and alloys, composite materials, polymers, semiconductors, high-temperature superconductors, magnetic materials, catalysts, biological macromolecules and subcellular structures, minerals, chemicals and petrochemicals, and atoms and molecules, the kind of information that will flow from the ALS will be of direct interest to industry.

Lawrence Berkeley Laboratory, founded by Ernest O. Lawrence in 1931, has a long history and an extensive base of experience in building and operating large scientific facilities, especially those based on accelerators. The ALS is benefiting from this expertise. An exceptionally strong and experienced team of scientists and engineers is dedicated to make the ALS succeed. The Laboratory also has a considerable experience operating national user facilities and a demonstrated commitment to doing so; an example is the National Center for Electron Microscopy, which offers a broad array of imaging and analytical capabilities down to atomic length scales to a user community spanning many disciplines.

Our initial experimental program will tap the talents of industrial scientists in semiconductors, magnetic materials, surface science, and microfabrication. For example, the ALS will serve those interested in developing fabrication technology for micro- and nanostructures, as well as for characterizing them. And we are working hard to broaden further the level of participation by industry to complement the extensive representation by scientists from the nation's universities and from our federal laboratories. We see industrial participation in

the ALS scientific program as a significant factor in boosting our nation's competitiveness in a global economic arena. This is intrinsic to our technology transfer mission.

Along with the scientific promises that we expect to see at the ALS, there are also severe challenges to be surmounted in order to make full and effective use of the facility. Some of these are technical, as the ALS is advancing the state-of-the-art in several areas. In accelerator design and technology, we have to build a machine that can store a beam of electrons racing at nearly the speed of light for several hours (long enough for the electrons to travel to the planet Neptune), all the while maintaining the beam in an area about the same as that occupied by a human hair. In magnet design and technology, we have to build mechanical structures strong enough to withstand magnetic forces exceeding eight and a half tons while maintaining dimensional stabilities once again comparable to the width of a few human hairs. And, in x-ray optical design and technology, we have to build precision optical systems that can stand up to blowtorch intensities of x-ray beams without losing their ability to guide and focus the beams with no loss in fidelity.

As severe as these challenges are, we are meeting them, and we plan to have the world's brightest source of x-rays when we open our doors to a diverse user community in April 1993. Providing x rays to eager scientists, however, is only the first step toward full and effective utilization of the ALS.

Following the normal practice for Department of Energy national user facilities, our construction budget (total estimated cost $99.5 million) provides for a basic facility only partially equipped with experimental equipment and laboratory space for our visiting scientists. It was expected that the most fruitful experiments would become apparent after scientists gained experience with the capabilities of the ALS during its early years of operation. Funding for needed beamlines and other experimental equipment would then be proposed to DOE, other Federal agencies and especially to industry. This has been the very successful strategy at other BES facilities.

What we are finding, however, is that the user community has already identified severe near-term requirements that, if not met, will limit our ability to serve our scientific constituents and their ability to exploit the scientific opportunities offered by the ALS. We are, of course, hard at work on strategies, including new initiatives, for addressing these needs. At the same time, we have become aware of a counterproductive proposal to "recover reasonable operating costs" from non-proprietary users, especially industrial users, of the ALS and the other Department of Energy national user facilities. Such a plan would severely curtail opportunities for industrial participation by reducing resources that could be exploited by non-industrial users in support of the Department of Energy mission, all the while providing little extra income to the federal treasury.

The Advanced Light Source

The ALS is a synchrotron-radiation source. Electrons are forced to follow a curved trajectory, which makes them emit light known as "synchrotron radiation." (The term "light" is used here in the general sense of electromagnetic radiation; at ALS energies, the radiation will be in the ultraviolet and x-ray regions of the spectrum.) The electrons circulate for many hours at a constant speed approaching the speed of light in a type of accelerator called an electron storage ring. In the places where storage-ring magnets bend, the electrons emit sweeping beams of intense x rays. The quality of synchrotron radiation can be enhanced still further by inserting periodic magnet arrays in the straight sections of the storage ring between the arc segments. These magnetic insertion devices (called undulators and wigglers) bend the electrons along an undulating path, thereby generating more synchrotron radiation .

For scientists interested in seeing into the nature and behavior of matter in all its many solid, liquid, and gaseous forms, x-rays are a particularly useful form of light. With wavelengths reaching down to the size of atoms and molecules, x rays are highly penetrating, and they can deposit energy when they are absorbed by matter or otherwise interact with it. In research, these properties of penetration of and interaction with matter are exploited. Scientists record some combination of behaviors, such as what x-ray wavelengths pass through a sample, how much the x-rays are attenuated during their transit, and what direction they take on emerging from the other side, as well as changes in the properties of the sample itself while it is being irradiated. In this way, they are able to gain insight into structural materials, such as alloys, composites, and polymers, into electrical and magnetic materials, such as semiconductors and permanent magnets, into biological materials, such as cells and their contents, and into atoms and molecules.

The ALS is important because, for the types of scientific investigations that characterize the forefront of research today, the ordinary x-ray tube used for routine medical diagnostics is far too feeble to be profitably exploited, and x-ray lasers are only beginning to be developed. Instead, it is the bright light from synchrotron sources that provides the foundation for a dramatic increase in the usefulness of x rays in research. In part, this is because the radiation is far more intense than that available from conventional x-ray tubes and discharge lamps; in part, it is because the researcher can select the wavelengths of interest at will.

The ready availability of these and other highly desirable properties has, in fact, driven the evolutionary development over the last quarter century of facilities dedicated to the generation of synchrotron radiation. In the first generation, scientists set up their experiments around electron synchrotrons and storage rings whose prime mission was high-energy physics, a so-called parasitic mode of operation. In the second generation, storage rings were designed specifically for the production of synchrotron radiation. Beginning with the ALS in 1993, so-called third-generation synchrotron sources will be coming on line in the United States, Europe, and Asia. These third-generation facilities use undulators and wigglers to

produce either "soft" x rays (lower energy, longer wavelength), as at the Advanced Light Source, or "hard" x rays (higher energy, shorter wavelength), as at the Advanced Photon Source.

The storage rings at these facilities are designed to extract light of the maximum brightness from of the electrons in two ways. First, the rings contain straight sections to accommodate long undulators (typically 16 feet in length at the ALS) that have up to 100 or so magnetic periods. In general, the brightness of the x-ray beams increases directly with the number of periods, thereby putting a premium on long undulators with many periods. Second, the rings are designed to have electron beams with a small cross section and a small angular divergence. This combination makes it possible to generate radiation that is a factor of 20 or more brighter (depending on the x-ray wavelength) than the radiation from existing, second-generation sources. In the past, such dramatic increases in brightness have always led to qualitatively new developments in studies of matter.

High brightness will particularly benefit researchers in both the physical and the life sciences who hope to image structural details down to distance scales of about 100 angstroms by means of x-ray microscopy. Conceptually, an x-ray microscope is analogous to a conventional optical instrument. However, several technologies, including the x-ray source (i.e., the ALS), the optics, and the detector, are only now reaching the level of development required to implement the x-ray version.

X-ray spectroscopy is an equally important beneficiary of high brightness. In spectroscopy, scientists measure the response of a sample to radiation of different wavelengths (i.e., to a spectrum of radiation). With high brightness, enough x-rays can be focused to a small spot on a sample to record a high-quality spectrum. By moving the spot around the surface or by the use of imaging optics, the experimenter can record a spectrum for each spot. An example of why this capability may be useful arises from the study of semiconductor surfaces, which are mostly heterogeneous, making interpretation of spectroscopic data obtained from illuminating the entire surface difficult. With the ALS, spectral features could be directly associated with specific surface areas and structures.

High brightness and the naturally pulsed nature of synchrotron radiation bring the ability to observe short-lived or transient systems by means of time-resolved spectroscopy, imaging, and other experiments. For example, life scientists hope that, if radiation damage due to the x-ray exposure can be avoided or minimized, it may be possible to image changes in functioning biological cells and cellular structures in near-natural environments. The ultimate time resolution, made possible because there are enough x rays in a single pulse of bright synchrotron light to generate a useful signal, would be to follow events as they actually occur on a time scale measured in billionths of a second or less.

In sum, the high brightness of the ALS will open new areas of research while the facility continues to serve as a reliable source for experimental techniques that have proven their worth in solving problems in basic research and applied technology.

Status of the Construction Project

The ALS facility consists of an accelerator complex, a complement of 4 insertion devices, beamlines, and associated experimental apparatus, and a building to house this equipment. The state-of-the-art storage ring has 10 straight sections available for a total of 10 insertion devices (undulators and wigglers). Initially, 24 ports for high-quality radiation in the curved arcs (bend-magnet ports) will also be available. Almost 60 beamlines are potentially available to guide the ALS x rays to researchers in experimental areas arrayed around the outside of the storage ring. In the normal operating mode, the radiation will comprise short pulses lasting about 30 trillionths of a second and coming at intervals of 2 billionths of a second.

Appropriation of the $99.5 million construction cost began in fiscal year 1987. As of fiscal year 1991, 93 percent of this amount has been appropriated, and the remaining $6.5 million is in the President's fiscal year 1992 budget request. Commissioning of the ALS technical facilities is supported by Department of Energy operating funds. With the end of the formal commissioning phase in March 1993, the ALS will be available to the user community in April 1993.

Conventional facilities construction is nearly complete. The ALS will occupy a renovated and enlarged version of the domed hall that once housed the historic 184-Inch Cyclotron. When the 184-Inch was being built in 1940, its size required Lawrence to move his radiation laboratory from the University of California at Berkeley campus to the hillside site that became LBL. This dome has long been a local landmark and is being preserved in the new building. In January 1990, we took beneficial occupancy of the renovated 21,000 square-foot area under the dome. Shortly thereafter, we began installation of the part of the accelerator complex that generates and accelerates electrons before injecting them into the storage ring.

The injector system has two major components: a linear electron accelerator (linac) and a roughly circular "booster" synchrotron. The linac is now working up to its full design energy of 50 million electron volts, thereby demonstrating not only that all its subcomponents are in working order but that they work together. Further commissioning will concentrate on increasing the beam current and fine-tuning other performance characteristics in preparation for commissioning the booster synchrotron, which will accelerate the electrons to their final energy of 1.5 billion electron volts. All major subcomponents of the booster have now been installed, and preliminary testing of the electronic systems, such as power supplies, is under way. We hope to begin booster commissioning late next month.

This month, the conventional facilities contractor turned over for occupancy the second portion of the ALS building, a 60,000 square-foot annular addition. The electron storage ring and the experimental areas will be enclosed by this part of the ALS building. At this time, we have essentially completed manufacture of the magnets that guide and focus the electron beam as it circulates in the storage ring. We are in the process of assembling the unique, machined-aluminum vacuum

chambers through which the electrons travel. The magnets and the vacuum chambers will soon be affixed to support structures called girders before installation in the new building. The first girders should be in place in May or June. Commissioning of the storage ring is scheduled to begin next spring, leaving approximately one year before the end of the construction project.

We are also making rapid progress on what we call the experimental facilities—the insertion devices and the beamlines. Engineering designs are well under way for the 4 initial insertion devices. The design philosophy is to create a generic design, thereby reducing engineering and fabrication costs and enhancing maintainability. The goal of very high brightness imposes unusually tight tolerances on the magnetic-field quality and thus on the mechanical structure of the undulators. To minimize the undulators' and wigglers' effects on the stored electron beam also makes it necessary to place severe restrictions on random magnetic field errors in these devices. Taking all error sources into account, our physicists have arrived at a magnetic-field error budget that allows for a net error of 0.25% in the most stringent case. One indicator of the precision being sought is that the separation between the opposing pole tips of the magnets in an undulator must be uniform to within about 10 millionths of an inch for a linear array of almost 200 poles spanning a distance of 16 feet, while a magnetic force of, in the worst case, more than 8.5 tons is pulling the poles together. Construction of test assemblies is now in progress. By the spring of 1993, we will have learned how to operate the storage ring effectively with at least four insertion devices installed.

Engineering design of ALS beamlines is now under way. The high brightness of the ALS x-ray beams has created new challenges for optics designers . The most serious limitation is that of optical fabrication tolerances for various optical elements. It is difficult to fabricate aspheric optical surfaces (paraboloids, ellipsoids, toroids, etc.) accurately enough to take full advantage of the undulator source. For example, the beam size and divergence of light from our undulators are exceptionally tiny. Typically, the beam size as it emerges from an undulator is 330 micrometers in the horizontal direction by 65 micrometers in the vertical, and the divergence is 40 microradians horizontal by 30 microradians vertical. (A human hair averages somewhat less than 100 micrometers in diameter.) The small beam size requires very tight tolerances for optical components in the two common measures of optical surface quality, figure and finish, to avoid loss of light and to maintain high spectral resolution. Moreover, the x-ray beam power can reach to several kilowatts per square centimeter. The requirement of controlling thermal distortions and stress complicates the design (for example, it is necessary to use water-cooling without compromising the ultrahigh-vacuum environment) and limits the choice of materials. To meet these challenges, our strategy is to use spherical surfaces for all mirrors and gratings and to actively water-cool the optics.

Assembling the Scientific Program

The ALS will support an extensive research program in a broad spectrum of

scientific and technological areas in which x rays are used to study and manipulate matter in all its varied forms. New opportunities for research in materials, interface, and surface science, in atomic and molecular physics, in chemistry, in the life sciences, in earth science, and in x-ray optics will be available. The ALS will also serve those interested in developing the fabrication technology for micro- and nanostructures, as well as for characterizing them.

The initial scientific program emphasizes the high brightness of the x rays available from the ALS. The program is being implemented by means of participating research teams (PRTs) consisting of investigators with related research interests from one or more institutions. PRTs will work with insertion devices on bend magnet beamlines. PRTs develop and maintain the experimental apparatus, and in return for its commitment, each PRT receives a guaranteed fraction of the ALS operating time at its beamline. However, many of the scientists working at the ALS will not be full-time users. To accommodate these independent investigators, which may include many industrial users, running time at each beamline will also be made available, through a proposal process, to investigators not affiliated with a PRT.

Our PRT approach is modeled after that pioneered by the National Synchrotron Light Source at Brookhaven National Laboratory. The virtues of the PRT system are at least twofold. First, PRTs bring important resources into the facility in the form of equipment, personnel, and funds. At Brookhaven, for example, the cumulative financial investment of some $120 million has been more than double the Department of Energy investment in the form of a $50 million construction budget for the Phase I and Phase II NSLS projects. Second, giving the PRTs a stake in the facility gives them an important incentive to maintain their scientific vitality and creativity, which in turn is spread to others on the experimental floor.

Planning the scientific program went hand-in-hand with planning the ALS itself. As the technical plans developed, we held a large number of workshops devoted, initially, to identifying the scientific opportunities expected at a facility such as the ALS. As construction commenced, our workshops helped to identify key scientists and groups of scientists who would be nuclei for PRTs. In 1988 we issued a Call for Letters of Interest to begin the process of forming PRTs. Then, in the spring of 1989, we issued a formal Call for Proposals, which resulted in 18 proposals from both insertion-device and bend-magnet teams. Eight insertion-device teams have been approved. Four bend-magnet teams were approved in June 1990. Including three additional bend-magnet ports allocated to insertion-device teams, seven of the 24 available prime bend-magnet ports have been spoken for. More than 200 persons from universities, federal laboratories, and industry were represented in the first round of PRT proposals.

Full Utilization of the ALS for the Nation

Optimal utilization of a facility like the ALS requires ancillary equipment and standard laboratory space for preparation and followup analysis. For example,

samples frequently require special facilities for preparation (such as semiconductor crystal-growing systems or animal surgeries, to cite two widely disparate examples from microelectronics and life sciences). At the ALS, two instances have arisen, one in the chemical sciences and one in the life sciences, where such additional facilities are necessary to fully exploit the scientific opportunities available. They have both given rise to new initiatives that, if funded would become national user facilities in their own right: the Combustion Dynamics Initiative and the ALS Life Sciences Center.

Under the leadership of LBL Nobel laureate Yuan T. Lee, chemists from across the nation are supporting a joint LBL/Sandia National Laboratories proposal for the Combustion Dynamics Initiative. The LBL portion of the Combustion Dynamics Initiative, adjacent to the ALS, would be equipped with a wide variety of modern chemical dynamics instrumentation, including a free-electron infrared laser, several high-speed pulsed lasers, and molecular beam reaction chambers. Two beamlines, one from an undulator and one from a bend magnet, would feed radiation from the ALS into the facility. CDF users from around the nation would primarily pursue fundamental studies of chemical dynamics problems related to the mechanisms of combustion; these problems have great implications for both energy efficiency and environmental protection. The proposal is currently under consideration by the Chemical Sciences Division, Office of Basic Energy Sciences, of the Department of Energy.

Meanwhile, opportunities for x-ray microscopy and holography have excited the nation's biologists. In response, they have proposed a Life Sciences Center at the ALS—part of the larger structural biology initiative of the Office of Health and Environmental Research of the Department of Energy. A central thrust of the structural biology initiative is the belief that a detailed understanding of the structure of biological molecules and disease-causing agents will lead to an understanding of how diseases develop, and how they can be blocked. The Life Sciences Center would focus its attention on problems that could be addressed with undulator or wiggler radiation, such as x-ray microscopy or x-ray diffraction, respectively. The Life Sciences Center would also provide a host of ancillary facilities for sample preparation and characterization and for data analysis. Like the Combustion Dynamics Facility, the Life Sciences Center would be operated by LBL as a national user facility available for use by biologists from around the nation, with its own scientific program and staff.

The portion of the ALS construction project budget set aside for experimental facilities turns out to be sufficient for the construction of four insertion devices and two beamlines. The decision as to which insertion devices and beamlines to cover with ALS construction funds was taken with the advice of our Program Review Panel, a group of nine outside experts from the synchrotron-radiation community and from research fields represented in the scientific program. No beamlines from bend-magnet ports for users will be supported by construction-project funds. Thus the funds available from the construction project to support experimental facilities will not meet the PRTs' needs in carrying out the approved scientific program.

We have placed considerable responsibility on the PRTs to develop their own funding sources. With the exception of one PRT with a large number of participants from the IBM Research Division laboratories in Yorktown Heights (New York) and San Jose (California), all the PRTs are dependent primarily on federal agencies for support. Even the IBM-led PRT has academic members who are seeking federal funds. While all these groups have by this time made or are about to submit proposals, to date there is no firm commitment by any agency to fund any PRT.

The amounts of money being sought are significant. Of the insertion-device PRTs, we have two so-called Type As, which are responsible only for their experimental equipment; two Type Bs, which are responsible for their experimental equipment and their beamlines; and four type Cs, which are responsible for their experimental equipment, their beamlines, and their insertion devices. Instruments to equip and experimental area can cost $1 million or more. Beamlines to guide and focus light from undulators are almost $2.5 million when engineering and design costs are included. Insertion devices are in the $1-million-plus range.

In addition to the experimental facilities needed to exploit fully the large range of research opportunities at the ALS, there are significant needs for space for offices, light laboratories, and equipment storage for visiting scientists. Such space is not included in the scope of the ALS construction project. The construction project does include the basic structural work and rough finishing of a 27,000-square foot mezzanine above the ALS experimental floor. However, the space cannot be used before interior finishing and installation of numerous safety and environment protection features We estimate that completing the mezzanine would cost $4 million. If completed, the mezzanine would serve the needs of more than one hundred visiting scientists.

Construction and annual operating costs for several synchrotron-radiation and neutron-scattering national user facilities already make up a significant fraction of the operating budget of the Department of Energy's Office of Basic Energy Sciences. It is apparent that, if Basic Energy Sciences increased the fraction of its budget going to national user facilities sufficiently to bring the ALS up to its full complement of experimental facilities and space for users, the office's support of the principal-investigator-originated research programs would be crippled or its research support would otherwise be distorted. Also, newer and much larger user facilities will also be coming into operation during the next decade; for example, the Advanced Photon Source is now under construction at Argonne, and the Advanced Neutron Source is under study at the Oak Ridge National Laboratory.

The need for all three of these national user facilities, while supportive of a broad spectrum of fundamental and applied research across many scientific disciplines, has been justified primarily by their impact on the materials-research mission of Basic Energy Sciences. Their construction was highly recommended by the National Academy of Sciences in a study of major materials facilities and by the Department of Energy's own Energy Research Advisory Board. All three—the ALS,

APS, and ANS—were subsequently made part of the Department of Energy's Strategic Facilities Initiative. For these benefits to begin accruing, the ALS and its sister user facilities must be able to offer their user communities state-of-the-art experimental equipment and space in which to prepare and characterize their samples, analyze their data, and carry out associated tasks.

To us, this situation seems to be most directly addressable by increasing the level of support for the Office of Basic Energy Sciences. We at the ALS have always planned for a certain fraction of our experimental facilities to be underwritten by industry and by other federal agencies through grants and contracts to our users; that is part and parcel of our PRT system. Therefore, it is inappropriate to raise the base level of support for Basic Energy Sciences sufficiently to cover all perceived needs. However, the present level of support is too low to enable Basic Energy Sciences to carry out its research mission while at the same time adequately supporting its user facilities. Somewhere there is an appropriate middle ground where we can all carry out effective research and make full use of the forefront capabilities inherent in these Basic Energy Sciences facilities.

The Problems with User Fees

At this time I'd like to discuss a very significant concern for the utilization of the ALS and other DOE national user facilities. The issue is that of user fees. In the fiscal year 1990 Budget Reconciliation Act, the Congress requested a study by the Department of Energy of the assessment of user fees.

The great majority of visiting scientists at these facilities are supported by federal funds, so a user fee would result in little additional revenue. At the same time, imposition of fees would result in severe limitations on the productivity of many other user groups (many more, in fact, than would be requested to pay fees). It would also negatively impact the institutions that can most benefit from the research emerging from the user facilities.

It is important to recognize that research activities at these facilities are often collaborative efforts — efforts that involve researchers from industry, universities and national laboratories working together on common problems. These collaborations also provide unique educational opportunities for students to learn about the opportunities for pursuing their scientific career.

As a result of the unique opportunities for research made available by these facilities, non-federal sources, primarily industry, have made and are making significant investments of both equipment and highly trained personnel that enhance the overall utilization of the facilities. This investment results in a significant increase in the research opportunities and capabilities that the facility can provide for university researchers, Department of Energy programs, and other users. The non-federal investment made at the National Synchrotron Light Source at Brookhaven, for example, is estimated at $40 million, only slightly less than the construction cost (Phase I and Phase II) of $50 million.

The result of this kind of investment is a strong leverage of Department of Energy funds. There would be significant enhancement of the quality and the breadth of research supporting the Department of Energy mission and of our goals in the areas of economic competitiveness and education of the next generation of scientists and engineers.

The extensive collaboration between scientists from industrial, academic and national laboratory settings is one of the most important drivers of the high quality of research opportunities coming from the Basic Energy Sciences user facilities. This collaboration benefits the Department of Energy and the nation. The worst thing to do would be to put the barrier of user fees in the way. If user fees were implemented for non-proprietary research (full cost recovery is already required for proprietary research whose results are not made available in the public literature), it would make industry think twice about entering into such cooperative efforts and would destroy the many advantages of leverage of federal funds, of collaboration between industry, academia, and the federal laboratories, and of education. The level of non-federal investment in the facilities would shrink, the utilization of facilities representing a huge investment of public funds would be compromised, and perhaps many of the key research activities would be driven overseas to Japanese and European facilities.

I strongly recommend that no change be made in the existing policy, which has been so successful in promoting effective collaboration across the research spectrum and which has encouraged large, non-federal investments in the Basic Energy Sciences user facilities. It would not be in the best interests of this nation's technical and economic success to impose this barrier upon an endeavor we should be trying to facilitate. Moreover, it would run counter to the interest of the Congress in encouraging increased partnership between the public and private sectors.

Summary

In conclusion, I can assure you that the ALS is progressing on schedule toward completion within budget in the spring of 1993. We have an enthusiastic user community working hard to put in place world-class research programs in a broad range of basic and applied science and technology.

I want to thank the Committee for its past support for the Advanced Light Source; to cite the Department of Energy for its far-sighted Strategic Facilities Initiative, which recognized and is now taking advantage of the strengths of the Department of Energy multiprogram laboratories to develop the necessary next-generation facilities; and to congratulate our sister light sources for the impressive work that has laid the foundation for the ALS.

Mrs. LLOYD. Thank you.
Dr. Moncton.

STATEMENT OF DR. DAVID E. MONCTON, ASSOCIATE LABORATORY DIRECTOR FOR THE ADVANCED PHOTON SOURCE, ARGONNE NATIONAL LABORATORY

Dr. MONCTON. Madame Chairperson, and members of the subcommittee, I am pleased to appear before you again this year to give you a progress report on the Advanced Photon Source project at Argonne National Lab, and comment on a few issues of concern to us.

Before discussing the project, I would like to take the opportunity to thank your subcommittee for the strong support which you have given to us over the last few years, and which support has been vital to the success so far of the project.

As you know, the APS is being built to provide ultrahigh brilliance X-ray beams—as many as 68 of them—for research experiments to understand the structure of a vast range of technologically critical materials from catalyst, to pharmaceuticals. I have described the scientific program of the facility in more detail in my written text.

I want to turn to the funding status which Congressman Fawell alluded to a bit earlier in the hearing today.

The APS construction project is in its third year of a seven-year construction schedule, with funding through fiscal year 1991, $115 million has been provided out of the $456 million total estimated cost. That funding lags behind the original plan by about $6 million.

For 1992, the original plan was $92 million. That has been reduced to $90.4 in the President's budget. So far, we are showing a shortfall of $7.6 million over the original plan.

Also troubling in the R&D and Operating Fund category is a shortfall, which, through 1992, if the President's budget is approved as is, will have accumulated to approximately $5.9 million. Then we will have a shortfall of somewhere close to $14 million since the inception of the project. Now that is a relatively small percentage of the total so far. We can carry on without substantial impact in our schedule. But the issue of most concern to us is the restoration of those funds in the future years because that will mean if they are not restored, we will have to reduce the project scope, and it will present potential compromise to the ultimate effectiveness of the facility.

We are working together with the DOE to restore those funds. We hope you will see that restoration beginning in the 1993 budget.

The construction activities have begun on the site. We broke ground in June of 1990. Because of the limited time today and a picture being worth a thousand words, I did bring a photograph to show you the early stages of construction. I will provide that for your perusal. We are gratified to see that the Advanced Photon Source is beginning to take on its form on the Illinois site. We have just begun the solicitation of major construction bids. We are pleased to report that these have come in—these early bids have

come in with some significant cost savings, with costs below our original estimates.

Nevertheless, it is early and too soon to assume a lasting trend, but we are off to a good start with, as I said, most of the work still ahead of us.

The R&D program, which supports the accelerator and beam line construction, is also moving ahead aggressively. It is described in detail in my written text, but suffice it to say now that the substantial R&D program, which we have had underway for four years has given us every confidence that this machine will function as planned.

I would like to turn now to the user program. The APS facility will enable researchers to carry out research in a wide variety of scientific and technological fields, notably material science, structural biology, medicine, chemistry, physics, geosciences, and others. It will significantly enhance the Nation's prominence in both basic and applied sciences.

The users, of course, come from many segments of the R&D community, the nation's academic, industrial and government laboratories. I am pleased to report to you that last Friday, we received some 20 formal proposals to use the APS. This is five years ahead of our planned operations. These proposals speak for approximately two-thirds of the APS capacity. This is very gratifying to us to see the extent of the interest so far in advance of the actual functioning of the facility.

It should be noted that these proposals contain potential investments of approximately $200 million to supplement the money that the DOE is putting into the construction of the facilities. That is very gratifying to us.

This funding comes partly from Federal agencies, including the DOE, but also the DOD, NIH, NSF. But it comes as well from industries, from various university foundations and also from a number of states. This unique financial partnership between Federal agencies, industries and the states is testimony, I believe, to the leadership that the U.S. Synchrotron community is showing in forging new cooperative approaches to scientific research. You have heard about them from other representatives of Synchrotron facilities at the other laboratories.

I would like to describe some of the collaborative arrangements that we believe are unique, represented among these 20 proposals. One of them is, I think, particularly exciting to us. It is a collaboration which has been formed by nine prominent U.S. pharmaceutical companies.

It is not common for industries competing for the same market sector to carry out their product development research in collaboration. But in this case, we have nine companies that have formed a formal agreement to build beam lines at the APS which they will use cooperatively while protecting their individual proprietary rights to their own research.

We have seen, in addition to this industrial interest, we have seen partnerships forming between industry and university teams, which I think are very exciting, collaboration between MIT and IBM, that was born at the National Synchrotron Light Source at

Brookhaven, but it has been extended at the APS to include a Canadian University, McGill.

Other examples of industry-university collaboration are Exxon Princeton and DuPont Northwestern, AT&T and the University of Michigan.

So I think it is clear that we are catalyzing, if you like, new relationships between industry and universities. These efforts, I think, should be applauded for the willingness of the institutions involved to lower the barriers to collaboration so that the complementary strengths of the industrial and academic approaches could be fully utilized.

The Synchrotron researchers bring a substantial amount of non-Federal funding to enhance the DOE investment and proprietary researchers are currently charged a full-cost recovery fee. You have heard a number of individuals today speak about the user fee issue. I won't go into that in any particular detail.

I share the concern of a number of my colleagues here on that issue. I would just like to state that I certainly believe that now is not the time to institute a system for increased fees for Synchrotron users.

I would like to quote Frank Sprow, who is the Vice- President of Exxon Research and Engineering Company, in a letter to Deputy Secretary, Henson Moore. Mr. Sprow said that, "Rather than increasing revenue for the Government, the inevitable result of increased charges would be less competitive technology for America."

I would like to conclude by sharing my concern for the funding of the core material science program, which you have heard other people speak about today. The support that that program provides for the researchers who produce new materials, produce the new understanding and the new technologies that we have heard described here.

Facilities like Synchrotron and Neutron Sources are being built to serve this community. It would be of little consolation to me that the APS is a success as a construction project if the materials science community is not healthy enough to use it effectively. Indeed, I think the fiscal year 1992 budget is showing such a substantial shortfall that this may be a distinct possibility, at least at Argonne.

Thank you very much.

[The prepared statement of Dr. Moncton and the referenced photograph follow:]

Testimony Before the

SUBMCOMMITTEE ON ENERGY
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

by

David E. Moncton
Associate Laboratory Director for the Advanced Photon Source
Argonne National Laboratory

March 19, 1991

APS PROJECT STATUS

INTRODUCTION

Madam Chairman and members of the Subcommittee, I am pleased to appear before you again this year to give you a progress report on the Advanced Photon Source (APS) Project at Argonne National Laboratory, and comment on a few issues of concern to us.

The Advanced Photon Source is the U.S. entry in the scientific race to develop high-brilliance synchrotron radiation beams for research in the hard x-ray region. Critical to the future of materials sciences research and biomolecular structure studies at the submicroscopic level, this facility will provide 68 x-ray beam lines for use by scientists from our leading academic, industrial, and governmental laboratories. From its inception, the APS has drawn on the advice, expertise, and enthusiasm of a user community that already numbers in the thousands from half the states in the union. About 20 research teams and consortia have prepared detailed research proposals that include technical, management, and funding plans to develop the first complement of beam lines at the APS to begin research operations in FY 1996.

APS FUNDING STATUS

The APS Construction Project is in the third year of its 7-year construction schedule. Funding to date of $115 million out of the total estimated cost of $456 million lags behind the originally planned funding profile by $6 million. For FY1992, the original budget request of $92 million has been reduced to $90.4 million. Including prior-year reductions, this means that approximately $7.6 million of planned construction activities will be postponed. It is essential that these funds be restored to the project budget as soon as possible, in order to prevent adverse impacts to the project scope due to cost escalations caused by delaying work. We are working with the DOE to restore these funds beginning in FY93.

Also troubling is a $2 million shortfall in operating funding for planned R&D in support of construction in FY1990 and FY1991. The operating budget level planned for the APS in the DOE Basic Energy Science budget for FY1992 was reduced from $29.7 million to $25.8 million, a shortfall of $3.9 million. Loss of research funding will increase the technological risk of the project or pose costly delays, if designs need to be revised when an unexpected performance problem is discovered after fabrication of an untested design. Substitution of construction contingency funds to carry out vital R&D, when it is needed now, could later reduce our flexibility to absorb unanticipated costs and thereby threaten the project scope.

Although I am well aware of the severe budget constraints being faced by Congress at present, I urge you to keep the APS close to our planned funding schedule so that we can deliver a fully functioning facility to the American scientific user community on time and on budget.

CONSTRUCTION

On June 4, 1990, we broke ground for the $456 million national research facility, and we are just about ready to pour our first concrete as soon as the ground dries after the winter thaw. We have carried out much of the architectural, design, and scheduling work;

we have analyzed and mitigated all environmental impacts to wetlands and cultural resources; and we have completed our preliminary safety analysis report. RUST International, our construction management contractor, has located its team at the APS site and is placing contracts for site preparation, utility installation, and initiation of building construction. So far the bids for these items are coming in below the original estimates, probably reflecting the high degree of competition for construction projects these days, but it is too soon to assume a lasting trend. Nevertheless, I feel we are off to a good start with most of the work still ahead of us.

RESEARCH AND DEVELOPMENT

The R&D program that supports the accelerator and beam line construction effort has accomplished some significant advances during the past year. For example, in order to store particles in the storage ring for many hours at a time, essentially all gases must be removed from the path of the particles around the ring. Our scientists have now successfully linked five prototype vacuum chambers over 70 feet in total length and evacuated the system to ultrahigh vacuum. This increases our confidence that we will be able to reach our vacuum design specifications over the entire seven-tenths of a mile circumference of the storage ring. We have also completed a second prototype of a critical quadrupole electromagnet needed to focus the particle beam. Our magnetic field measurements on this unit show that we have improved the efficiency and quality of this key accelerator component, and so we can now proceed confidently with its production design. Two prototype rf acceleration cavities for the storage ring are being prepared for installation at our recently completed high-power, 352-MHz rf test station. After studying the performance of these two alternative designs, a final production design will be chosen. In the future, the rf test station will be used to assure the quality of procured cavities and other major rf power components before installation at the storage ring.

Key to the success of producing high-brilliance beams of x-rays at the APS is the use of precision arrays of permanent magnets known as undulators or wigglers. Construction of a 7.5-cm-period, 2.4-m-long APS prototype undulator was completed on time by Spectra Technology, Inc., and installed on the U5 straight section at the National Synchrotron Light Source at Brookhaven National Laboratory. The magnetic field parameters met or exceeded the original specifications providing considerable confidence in the manufacturing capability of U.S. industry for such devices. The undulator is now being used to study at lower brilliance levels the quality of light beams that can be produced and the performance of optical designs for use at APS. One such novel optical device is an x-ray lens that we have recently fabricated and used to focus an x-ray beam down to a spot size of a few microns that is the smallest ever achieved.

APS USERS PROGRAM

The purpose of the APS facility is to produce x-rays with unique characteristics for use in scientific and industrial research. The extreme brightness of these x-rays will provide new capabilities of research in many fields of science and technology, notably in the areas of materials science, structural biology, medicine, chemistry, physics, and the geosciences. The APS will significantly enhance the nation's prominence in both basic and applied sciences and will add significantly to the expansion of America's high-technology capabilities. The users of the APS come from different disciplines, and from the nation's academic, industrial, and government laboratories.

The users will gain access to the APS facility by submitting scientific research proposals to carry out the work. Because of the diversity, complexity, and cost of instrumentation needed to conduct research at the APS, users with like interests will form collaborative access teams. Typically, these teams will consist of members from academic institutions, industrial firms, national laboratories, or a combination. During the early operation of the APS in FY1996, about 300 principal investigators, members of such collaborative teams, will actively pursue their research. The synergy resulting from such teams will unite scientists from academia, the industrial sector and the national laboratories, providing a much-needed vehicle for technology transfer in this country. In addition, this team concept brings a variety of resources from academic and industrial worlds to facilitate the mission of the Department of Energy.

The cost of instrumentation for x-ray beam lines is considerable. In preparation for research during the early years of operation, about 20 collaborative teams at the APS will invest as much as $200 million for beam line instrumentation. This is nearly half the cost of the APS construction project. Such funds will come from federal funding agencies such as NSF, DOE, DOD, and NIH, as well as from the industrial partners, various university foundations, and state agencies. This unique financial partnership between federal agencies, industries, and the states is a testimony to the leadership that the U.S. synchrotron radiation community is showing in forging new cooperative approaches to scientific research.

Let me make some specific comments on the collaborative teams that are forming at the APS. The availability of bright x-ray beams at the APS will provide a new impetus to the scientists working on the molecular and supermolecular structure of living systems. Understanding the structure will lead to revelations regarding the mechanisms of cancer induction or viral afflictions such as polio, the common cold, or acquired immune deficiency syndrome (AIDS). In the above context, I want to mention a very special synergism that has developed among the pharmaceutical industries. It is not a common experience for industries competing for the same market sector to carry out their product development research in collaboration. For the APS, however, a collaborative team has been formed by nine prominent U.S. pharmaceutical companies that are pooling resources to collaboratively develop and build instrumentation for research. The team will look at the structure of biological macromolecules in order to facilitate the development of biologically active compounds for medicine and agriculture. This is an excellent demonstration not only of the importance of APS for the development of new drugs and agricultural products, but also of the willingness of a special industrial sector to work cooperatively at the APS.

Another development at APS involves collaboration among industry, academia and a foreign institution, the partners of the collaborative team being IBM, MIT, and McGill University, Canada. This enterprise brings financial resources to a federal facility not only from the computer giant, but also from a private foundation at MIT and from Canada. There are a number of other joint industry-university teams such as Exxon-Princeton and DuPont-Northwestern. All of these efforts should be applauded for the willingness of the institutions involved to lower barriers to collaboration so that the complementary strengths of the industrial and academic approaches can be fully utilized.

USER FEES

The outcome of research conducted at the APS will affect all walks of life. The computer, communication, medical, energy, health care, and pharmaceutical industries will all benefit. The dramatic advances that are anticipated in many of these important industrial sectors are being challenged by Japan and Europe, where x-ray facilities similar to APS are

being rapidly built. If America is to maintain its industrial competitiveness in the world, it is time to encourage close cooperation between the academic and industrial users of the major facilities such as APS for the benefit of the entire nation. Synchrotron users already bring substantial non-Federal funding to enhance the DOE investment and proprietary research is charged a full-cost recovery fee. Now is not the time to institute a system of increased fees for synchrotron users. Below we describe each segment of the APS user community and specifically discuss the impact of new user fees.

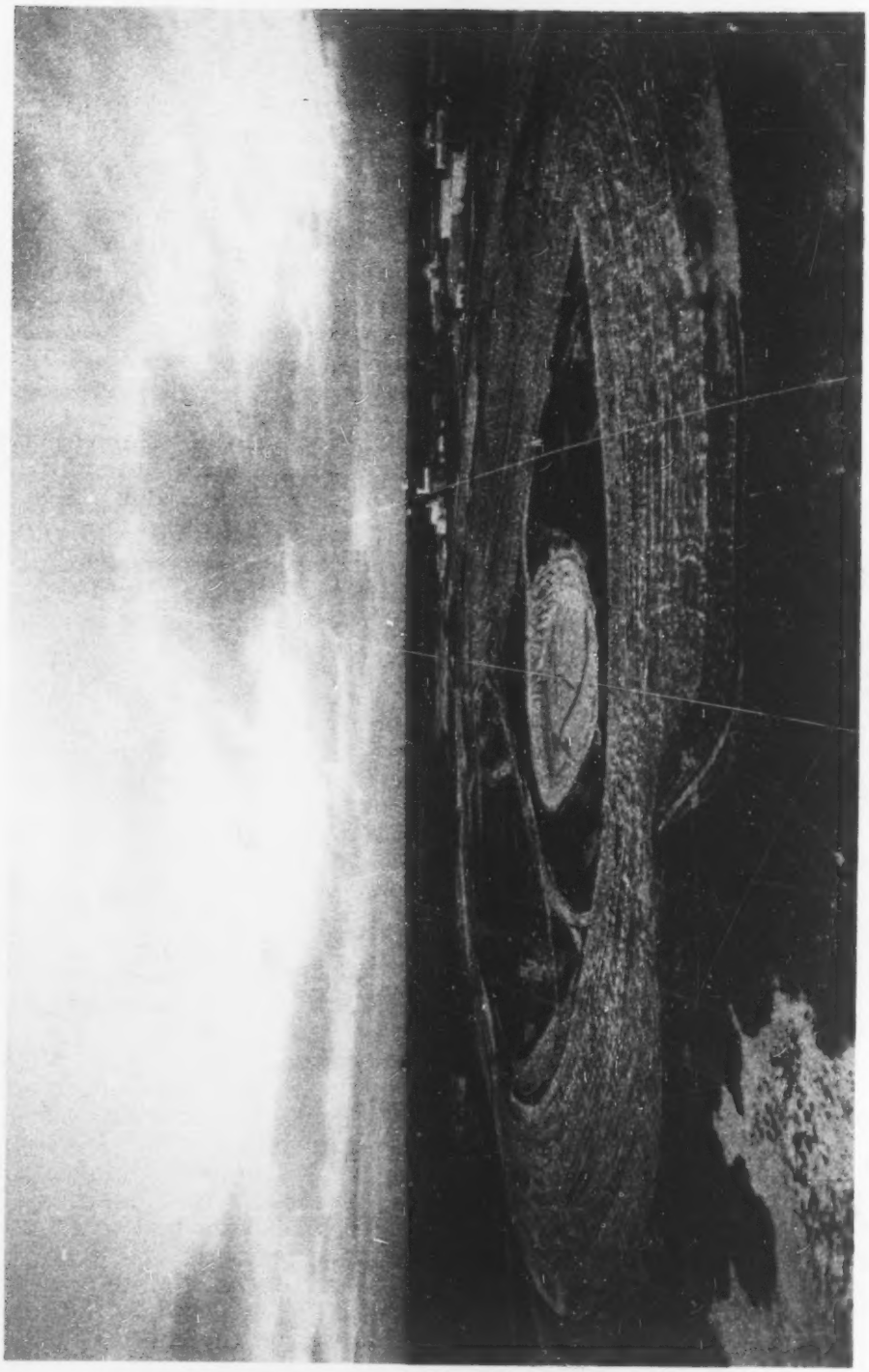
Proprietary Work by Industrial Users. This class of users already pay full cost recovery. There would be no additional revenues possible here unless DOE were to increase charges beyond recovery of full costs. It would be unwise to do this since industry is currently under substantial financial pressure to minimize long-range research. Undoubtedly, the consequence of DOE adding a profit margin to its recovery of costs would be to reduce the amount of proprietary work carried out rather than increase revenues.

Non-Proprietary Work by Industrial Users. The majority of industrial research consists of non-proprietary work. It is reviewed to assure DOE mission relevance and high scientific quality, and it is carried out predominantly on beamlines constructed and operated with industry funds. The DOE cost per sector to operate the overall facility, including 20-year amortization of construction costs, is similar to the industry cost to operate its sector including staff costs and 5-year amortization of beam-line construction costs. Because all the work is relevant to the DOE mission, it would be reasonable for industry to reciprocate by charging DOE to recover its costs. Since industry provides its beamlines 25% of the time for exclusive use by DOE or its designates, a reciprocal fee arrangement might actually increase total DOE costs.

Non-Proprietary Work by Foreign Researchers. There are currently about 40 synchrotron research facilities worldwide, including about 10 in the United States. The European Synchrotron Radiation Facility, similar to the APS, is currently under construction in France, about 2 years ahead of our schedule. An attempt to charge fees for use by foreign researchers would result in reciprocal charging arrangements by foreign governments, which would either lead to a net cost to DOE or result in severely reduced international collaboration. Furthermore, it would be highly detrimental to APS users wishing to get going early by using the ESRF in the interim before APS begins operations.

Non-Proprietary Work by Federally-Supported Researchers. The APS users community will have a large component that is funded by other Federal agencies such as the NSF, the NIH, or the DOD. Establishment of accounting systems to refer charges back to each of these organizations would create a substantial bureaucracy which would represent a net cost to the U.S. taxpayer. Furthermore, such costing procedures would undoubtedly reduce interagency collaboration as well as making it very difficult to manage a facility when revenues were uncertain.

In summary, I would like to quote Frank Sprow, Vice President of Exxon Research and Engineering Company. In a letter to Deputy Secretary Henson Moore, Mr. Sprow said that "rather than increasing revenue for the Government, the inevitable result of increased charges would be less competitive technology for America."



Mrs. LLOYD. Thank you, Dr. Moncton.

Dr. Appleton, we are happy to have you with us from Oak Ridge. Please proceed.

STATEMENT OF DR. BILL R. APPLETON, ASSOCIATE DIRECTOR FOR PHYSICAL SCIENCES AND ADVANCED MATERIALS, OAK RIDGE NATIONAL LABORATORY

Dr. APPLETON. Thank you, Madame Chairwoman. Madame Chairwoman and members of the subcommittee, it is always a pleasure to testify before this committee. In my opinion, over the years, this subcommittee has been a staunch supporter of science and technology and it has been a tremendous benefit to the Nation.

This afternoon, I am going to limit my remarks to the area of neutron science and I am going to give you a status report on the Advanced Neutron Source project.

Although neutron science is recognized worldwide as an essential tool in science and technology, it has been through some difficult times in recent years simply because it uses nuclear reactors in an ever-tightening regulatory environment. Nevertheless, there are a number of very positive things happening in neutron science. I would like to emphasize those in my remarks this afternoon.

The first bit of positive news I have is that the High Flux Isotope Reactor at Oak Ridge is back in full operation after a three-year shut-down and is providing the science community once again with neutrons for neutron scattering analysis, for the production of Isotopes, for medical use in cancer research, for studying materials an radiating materials that would be needed in our future energy systems, and a whole variety of research ranging all the way from biology to material science and engineering.

Oak Ridge and the Department of Energy have used this period of shut-down to establish what I believe is now the best and safest reactor operation at any research reactor. So it has been a time that we have used well.

This is not to say that there weren't lost opportunities as a result of the shut-down. If you look back, the HFIR shut-down coincided almost exactly with the discovery of the new high transition temperature superconducting materials.

Because neutrons are particularly sensitive probes of light atoms, such as oxygen which is contained in these materials and because the neutrons themselves are magnets that are particularly sensitive to magnetic properties of atoms and solids, neutron scattering has been mostly responsible for our current understanding of the structure and magnetic properties of these new materials. Of course, while HFIR was down, the other reactors had to be used and many of those reactors were European reactors.

The second bit of good news that I have is that the neutron science is alive and getting held here everyday. Everyday, there are new materials and new science on the horizon that need neutrons. A recent example of that that I was reminded of at the American Physical Society meeting, where I have been this week, has been the discovery of a third form of carbon.

We are all familiar with graphite and diamond, but scientists have now discovered this new material, which is made up of 60

carbon atoms that arrange themselves into a molecule and form a geometric sphere in the shape of a soccer ball. Measurable quantities of this material have already been synthesized and research samples have been made. At ORNL, as elsewhere, the structure of this new material and the dynamic properties of the molecular configuration are again being determined by neutron scattering because of the special sensitivity to carbon.

Even with HFIR down for the last three years, the number of users in the U.S. has continued to increase and has continued to rise to be over 1,400 per year.

We are also seeing an increasing interest from industry in the use of neutrons for everything from the development of new plastics to the use of neutron radiography or non-intrusive testing of operating systems, such as looking at lubricant and operating engines. At ORNL, we are looking at the possibility of establishing a facility to characterize the residual stress in machine parts because of the superior penetrating power of neutrons.

This brings me to the final bit of good news that I would like to share this afternoon. That is the status report of the Advanced Neutron Source. Construction of the Advanced Neutron Source at ORNL is an opportunity for the U.S. to gain preeminence in this very important field of science, and to exploit the escalating use of neutrons.

Both the HFIR and the HFBR will approach the end of their useful lifetimes by the close of this decade. Just as the Europeans exploited our earlier pioneering work at HFIR and HFBR to make ILL a superior reactor for its time, we now have the opportunity to capitalize on their experience in intervening years to make the ANS the best researcher reactor in the world.

As I discuss in my submitted testimony, ANS will be capable of delivering useful beams for some applications that are hundreds of times better than any current reactor in the U.S. Thanks to the continued support of Congress and this subcommittee, the funds requested in the President's budget for 1992 are sufficient to keep the ANS on schedule.

A synopsis of the recent history of the ANS given in my submitted text shows that from 1987 through 1990, the project was only able to move forward with the aid of funding specifically added by Congress. However, the President's request for a $24,6 million budget in fiscal year 1992 will keep us on schedule. Nevertheless, it is vital that we receive the full $24.6 million, or we will fall behind for the reasons that were discussed in relation to the other facilities as well.

Under this schedule, we shall be requesting a 1993 line item for the next phase of the project.

As you indicated, Madame Chairwoman, we think that is a very important step for us. This phase will allow us to do the preliminary design work, the safety analysis and the environmental studies that must take place before construction and authorization can be given.

That concludes my remarks. I will be glad to answer questions.

[The prepared statement of Dr. Appleton follows:]

Testimony of

BILL R. APPLETON

Associate Director for Physical Sciences and Advanced Materials
OAK RIDGE NATIONAL LABORATORY

ON NEW USER FACILITIES UNDER CONSTRUCTION OR PLANNED AT OAK RIDGE NATIONAL LABORATORY

before the
SUBCOMMITTEE ON ENERGY
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

March 19, 1991

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
Managed by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
under Contract No. DE-AC05-84OR21400

TESTIMONY
SUBCOMMITTEE ON ENERGY
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
MARCH 19, 1991

BILL R. APPLETON
ASSOCIATE DIRECTOR
OAK RIDGE NATIONAL LABORATORY

Madam Chairman and Members of the Subcommittee, it is always a pleasure to testify before this subcommittee. Over the years this subcommittee has been a staunch supporter of science and technology that has been of enormous benefit to our nation and society. I am particularly appreciative of the support you have given to the field of neutron science and the Advanced Neutron Source project. Although neutron science is recognized worldwide as an essential tool in science and technology, it has had difficult times in the U.S. because it requires the use of nuclear reactors in a tightening regulatory environment. The Advanced Neutron Source will be the first research reactor built in this country with safety and science integrated together in a manner that will yield the best research reactor in the world.

This afternoon I will limit my comments to the user facilities supported through the Department of Energy's Basic Energy Sciences programs. In particular, I will discuss the role of neutron research and the importance of the Advanced Neutron Source project for regaining our leadership in several areas of science critically important to our future technological and economic needs.

Scientific Opportunities in Neutron Scattering

Neutron science encompasses an unusually broad spectrum of scientific disciplines, both because of the fundamental properties associated with the neutron and because of the unique way the neutron interacts with matter. This utility is reflected in a user population in both the scientific and industrial communities that has grown to over 1400 scientists and engineers per year. Commenting on the relevance of neutron science, D. Allan Bromley, the Advisor to the President for Science and Technology, has stated, *"In the four decades since the first controlled nuclear chain*

reactor made them available in abundance, neutrons have had a revolutionary impact on science and technology."

Condensed Matter Physics. In the area of condensed matter physics, neutrons have a number of unique characteristics that make them ideal probes. First, they have large penetration depths compared with other particles such as x rays or electrons and are thus sensitive to bulk properties. Since neutrons are magnetic, they provide unique information on bulk magnetic structures and low-energy magnetic and lattice dynamical excitations. It has been very important, for example, in determining the structure and magnetic behavior of the hew high-transition superconductors. There is no systematic dependence of the scattering power of neutrons on atomic number as with x rays which have enhanced sensitivity to heavy nuclei in matter. Neutrons are ideally suited for studying light nuclei. Consequently, neutrons and x rays are complementary probes.

Materials Science and Engineering. Materials science and engineering (MS&E) is emerging as a unified field that includes the entire innovation process from the inception of a new material, through its development and incorporation into a functioning system, to commercialization. Two recent studies by the scientific community have emphasized the importance of MS&E to the future economic competitiveness of the U.S. and the well-being of our society. The National Research Council report *Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Age of Materials* clearly identified the tremendous opportunities in MS&E and established the importance of materials to the future economic well-being of major industry groups in the U.S. A more recent report *A National Agenda for Materials Science and Engineering* emphasized the need for a strategic, goal-oriented planning process for MS&E and the importance of improving cooperation among the industrial, university, and government laboratory sectors of the research community in order to accomplish these goals in a synergistic manner. Techniques such as neutron scattering have proved essential for understanding the interactions of materials on an atomic scale and relating this understanding to macroscopic properties and even for examining the engineering characteristics of operating systems such as lubrication flow in operating engines. Examination of the number of hands-on users at neutron facilities in 1988 shows that 30% of all use was for MS&E.

Industrial Research. All indications are that neutron research is becoming increasingly important to U.S. industry. The use of neutron facilities by industry has steadily increased. Many of the firms that used neutrons early have continued to use them. Exxon used their neutron research results from HFIR on the development of a new polymer material in a national advertising campaign and are now investing in the new cold source research facility at the National Institute for Standards and Technology (NIST). Rolls-Royce, the British firm that builds the only jet engines efficient enough to take a fully-loaded Boeing 747-400 nonstop across the Pacific, has had an extensive neutron-based R&D program in its Aerospace Division for two decades. Industrial interest in the use of neutrons for residual stress analysis of finished parts has led to the development of an exploratory stress analysis center at ORNL.

Polymer Science. A significant fraction of the synthetic materials and plastics we use every day including our clothes, room furnishings, automobile and airplane parts, etc., are made from polymer materials. Since polymers and plastics are made up of light atoms (e.g., carbon and hydrogen) and since neutrons have a special relative sensitivity to light atoms, neutron scattering has become the probe of choice for scientific studies of polymers and industrial development of new materials. This is a good example of the utility of cooperative user facilities for our industrial development because although neutron scattering is essential in understanding and developing new polymers. It is not practical, nor probably desirable, for individual companies or industries to build and operate a nuclear reactor or other neutron facility.

Biology. Fundamental advances in biology, such as the genome project, are largely based on understanding the structure of complex biological molecules so we can relate structure to function. Neutron scattering is particularly suited to such studies. Recent results include the structure of the ribosome and of the energy-transducing protein bacteriorhodopsin, the organization of water at protein surfaces, and transition dynamics in proteins. The use of neutron scattering in biology is expanding rapidly and promises new approaches for solving problems in medicine, agriculture, and other areas of biotechnology.

Isotope Production. The production of radioactive isotopes in reactors such as the High Flux Isotope Reactor (HFIR) at ORNL is important for a wide range of

applications. There are over 300 radioactive isotopes with widely varying lifetimes from 1 day to 10,000 years or more. They have widely varying physical, chemical, and biological properties that have been tailored for use in food technology, agriculture, energy supply, public health, medicine, industrial technology, and national security. In the U.S. alone approximately 40,000 medical procedures each day make use of radioisotopes.

In nonclassified defense uses, isotopes produced in HFIR are used for aircraft and other radiography and for explosives detection in counter terrorism. A primary use of radiography is for nondestructive evaluation of aging aircraft such as the F-111 for life extension. HFIR is the sole source of many special isotopes such as ^{252}Cf which is used in cancer treatment and military applications. Once HFIR reaches its end of life, the ANS will be the only production facility in the western world for these materials.

Neutron Physics. The intrinsic properties of the neutron as one of the three main constituents of matter along with the proton and electron continue to be a rewarding area for fundamental studies. For example, the 1989 Nobel Prize in Physics was awarded to Norman Ramsey for such studies. It is informative to note that although Professor Ramsey initiated his studies of the neutron at reactors in the U.S., he has worked the last 10 years or so at the Institut Laue-Langevin (ILL) in France because of the larger neutron flux there. Further advances will require the flux levels and new instrumentation such as that proposed at ANS.

The Need for an Advanced Neutron Source

The need for an Advanced Neutron Source in the United States has been recognized for many years in the scientific community. Construction and operation of the HFIR at ORNL and the High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory beginning in the mid 1960's quickly demonstrated the enormous potential of neutron science. The European community seized on the importance of this field and used the U.S. experience to construct a new, higher flux reactor, the ILL, which began operation in the mid 1970's at Grenoble, France.

Although it was scientists in the United States who started the field of neutron scattering and pioneered in its development, we have fallen critically behind in the

intervening years. In the 1972 National Academy of Sciences report *Physics in Perspective*, it was stated that *"in Europe this field (neutron scattering) is regarded as of prime importance and promise. A $95 million Franco-German facility devoted primarily to slow neutron interaction with condensed matter is about to begin operation in Grenoble. Although this field originated in the U.S., unless drastic action is taken, Supremacy will pass to Europe within the next 5 to 10 years."* Such action was not taken and the prediction, unfortunately, was correct. In 1980, the Review Panel on Neutron Science reported to the Department of Energy that *"until the mid-1970's the United States dominated the field with some 2/3 of the seminal contributions originating here. However, since the mid-1970's when ILL reached its fruition, the opposite has been true ... there is reason to believe that this trend may continue to accelerate."*

Beginning in the 1980's numerous scientific evaluations including the Rush report, the Shelter Island Workshop and the Seitz-Eastman report all recognized the emerging importance of neutron science and that the U.S. was continuing to fall behind. In 1984 a blue-ribbon panel was assembled by the National Research Council to establish priorities for major materials facilities needed in the U.S. to meet this challenge. The Committee on Major Materials Facilities (Seitz-Eastman Committee) gave the highest national priorities to the Advanced Photon Source (now in construction) and the Advanced Neutron Source (now in conceptual design). In a reevaluation of the need now for the ANS, the Chairman of the Neutron Scattering Panel of the Seitz-Eastman Committee wrote to the Secretary of Energy in 1990 that *"all of the conclusions reached in 1984 remain valid today. Indeed, if anything, the arguments ... are even more persuasive today than they were in 1984."* James Krumhansl, past president of the American Physical Society, testified to Congress in 1990 that *"light sources and neutron scattering facilities ... are the kinds of facilities for physics which have the greatest immediate and near-term relevance to technology and competitiveness. In fact, by contrast to the Japanese and Europeans in this field, in this country we have fallen critically behind."*

Projected Use of the ANS

The ANS is being planned from the beginning as a facility that will be available to a broad spectrum of the scientific community. To implement this goal, a National Steering Committee for ANS (NSCANS), populated with leading scientists from all

sectors of the neutron science community, has been involved from the very beginning in the planning and design of the reactor and the associated experimental facilities. This group has held workshops and meetings to anticipate the needs of the scientific and industrial communities and this information has been incorporated into the reactor design. Instruments will be designed with foresight and flexibility recognizing that the needs and opportunities of the science will evolve. The entire ANS facility will be planned to provide a safe atmosphere suitable for research separate from the reactor but one which can be operated with the proper security and controls required by the current regulatory environment.

The number of scientists expected to use ANS is in excess of 1000 per year. Although the exact number cannot be predicted, current use patterns suggest that this is a conservative estimate. Table 1 shows the actual "hands-on" user profiles at U.S. neutron facilities compiled by the Division of Condensed Matter Physics of the American Physical Society. This study shows that currently a little more than 1400 scientists use U.S. neutron facilities. There are other users who frequent ILL, or who use isotopes produced at the reactors by others. Since the user base grows each year, we believe that the estimate of 1000 users in the year 2000 is conservative.

The use of neutron scattering by industry is also growing rapidly as already stated, and the increased capabilities of ANS will likely expand the number of industrial users in the future. Some appreciation of the breadth of industrial interest can be seen from the list of recent industrial users in Table 2.

The primary focus of the ANS will be multidisciplinary R&D. Based on current uses of the best research reactors, the ANS will provide unique results in physics and astrophysics, nuclear and fundamental physics, condensed matter (solid and liquid state) physics, surfaces and interfaces, biochemistry, structural biology, materials science and engineering, archeology, materials irradiations and analysis, and isotopes for research, medical, and defense applications. This diversity of users emphasizes the "small science" aspects of the ANS, unlike large-scale facilities built for single purpose research. All experience shows that such research centers generate a wealth of new science through the synergistic effects of having many disciplines on the one site and that the user base grows rapidly as new ones are discovered. This growth in the user base has a very positive educational impact since it occurs mainly through new students being attracted by exciting new science.

Table 1. Hands-on User Profiles at Neutron Facilities

Neutron facilities	HFIR	HFBR	NIST	IPNS	LANSCE	MURR	Total No.	Total %
Local	92	41	85	57	24	187	486	34.7
Govt labs (other)	9	6	37	18	12	41	123	8.8
University (other)	76	92	68	89	28	142	495	35.3
Industry	24	20	35	20	5	58	162	11.6
Foreign	20	47	25	17	11	15	125	9.6
Total	221	206	250	201	80	443	1401	100.0

Table 2. Some Industrial Users of Neutron Research Facilities

3M Company	EG&G	Monsanto
Aerojet Heavy Metals	EXXON	Mound Laboratories
Aerospace Corp	Firestone Tires	Nuclear Metals
Allied Chemical	Ford Motor Company	OptoLine Corp
Allied Signal	GEN Corp	Philips
AMOCO	General Electric	Polaroid Corp
AT&T Bell Laboratories	General Motors	Raychem Corp
BellCore	GTE Laboratories	Rolls Royce
BP-America	Goodyear Tires	Schlumberger-Doll
Charles Evans Assoc	Hercules, Inc.	S. C. Johnson & Son
Chevron Oil	Hoechst-Celanese	SRI, Inc.
CIDTECH	Hughes, Malibu	Standard Oil
Corning	IBM	Unilever
Directed Technologies	ICI	Union Carbide
Dow Chemical	Intel Corp	Westinghouse
E.I. duPont	Kraft	W. R. Grace
Eastman Kodak	Lockheed Missile	Xerox Corp

Status of ANS

Construction of the Advanced Neutron Source at ORNL is an opportunity for the U.S. to regain preeminence in this important science discipline and exploit the escalating use of neutrons by our industry. Both the HFIR and HFBR will approach the end of their useful lifetimes by the close of the decade. Just as the Europeans exploited the pioneering work at HFIR and HFBR in making ILL a superior reactor for its time, so we have the opportunity to capitalize on their experience in the intervening years to make ANS the best research reactor in the world.

A comparison of the increased capabilities that are possible with ANS compared with HFIR, HFBR, and ILL are given in Table 3. The increased capabilities for ANS result not only from the higher flux but also from new instrumentation developments integrated into the reactor design. For example, the effective number of cold neutrons per second delivered to users at ANS will be 600 times that possible at HFBR and 23 times that available at ILL. The availability of increased neutron flux at all neutron energies will extend known capabilities and open new vistas in neutron scattering, materials irradiation and testing, isotope production, chemical analysis, structural biology, nuclear and neutron physics, and new areas yet to be discovered.

The ANS project is a multi-institutional effort involving a broad spectrum of the neutron science community as well as the DOE. We are currently collaborating with ANL, BNL, INEL, LLNL, LANL, and several universities. The National Steering Committee for the Advanced Neutron Source (NSCANS) continually provides guidance as to the scientific and instrumentation needs of the project. All aspects of the project have been subjected to extensive review by independent experts at frequent intervals since the beginning of the project. A list of the recent reviews, workshops, and meetings is shown in Appendix A.

Table 3. A Measure of Capability: Effective Neutrons per Second Available to Users[a]

Neutron energy band	HFBR[b]	HFIR[c]	ILL[d]	ANS[e]
Hot	0	0	470	470
Thermal	350	410	1600	11500
Cold	30	0	700	16000
Very Cold	0	0	35	250
Ultra Cold	0	0	460	2800

(a) Number of beams times useful area of each beam times peak flux in reflector ($10^{19}s^{-1}$).
(b) 40-MW operation.
(c) 85-MW operation.
(d) Beams available to users are over demanded by about a factor of 4.
(e) Minimum requirements assessed by the scientific community through four national workshops and by the National Steering Committee for the Advanced Neutron Source.

Thanks to the continued support of Congress and this subcommittee, the funds requested in the President's budget for FY 1992 are sufficient to keep the ANS on schedule. A synopsis of the recent history of the ANS given in Appendix B shows that from FY 87 through FY 90 the project was only able to move forward with the aid of funding specifically added by Congress. However, the President's request for a $24.6 million budget in FY 1992 will keep us on schedule. Nevertheless, it is vital that we receive the full $24.6 million. Under this schedule, we shall be requesting a 1993 line item for the next phase of the project, which is the preliminary design work, safety analyses, and environmental studies that must take place before construction authorization can be given.

Last year's Congressional action that provided $12 million for ANS in the current fiscal year has allowed us to begin negotiations with an Architect-Engineer (Gilbert Commonwealth working in association with the University of Tennessee; Air Products and Chemicals, Inc.; the architectural firm of Kling, Gmitter; Geotek Engineering Co.; DRS/Hundley; and others). This outstanding group will collaborate with us in completing the conceptual design by the summer of next year. The technical work has accelerated this year, with reference concepts selected for the reactor cooling system, the containment building, and the reactor core assembly. These concepts represent significant safety enhancements in the design of high power research reactors.

DOE User Facilities: A New Era of Cooperation

I would additionally like to take this opportunity to comment on the beneficial impact the DOE user facility concept has had over the years and to recommend against altering this policy by charging universal user fees.

Over the years the Department of Energy's Basic Energy Sciences programs have assumed a national responsibility to construct and operate major user facilities for the benefit of all of U.S. science. Beginning in 1979 the DOE initiated a policy which has ushered in a new era of industry, university, and national laboratory cooperation. This policy, adapted in response to the increasing need in U.S. universities and industry for access to these unique facilities, designated certain major facilities as user facilities open to scientists and engineers outside the DOE. Over the intervening years of operation, three modes of access to these user facilities have developed. The first is free access to any group of researchers who perform R&D of programmatic interest to DOE and publish their results in the open literature for the benefit of all of science. The second type of access, mostly to U.S. industrial users, permits proprietary research in return for full cost recovery. The third type which has developed in recent years is participating research teams where equipment at the facility is funded and operated by cooperating teams from universities, industry, and government laboratories. These participating research teams receive a guaranteed fraction of time on the facility but are required to share their instruments with other users the remaining time.

These modes of interaction have made it possible for many small research teams to have access to major facilities and unique instrumentation that no single team could afford alone; for R&D partnerships to be formed among industry, university, and government laboratory researchers that bring essential multidisciplinary expertise together to solve critical national problems; and for U.S. industry to do proprietary research that gains them a competitive advantage.

The effect this stimulus for cooperative interactions has had can be gauged from the scope of the ORNL guest and user interactions. In FY 1990 ORNL had 2915 outside guests and users. This is a 24% increase over guest assignments in FY 1989. Oak Ridge National Laboratory currently has eleven user facilities and is scheduled to initiate two additional industry-oriented user facilities within our High Temperature Materials Laboratory in FY 1992. In FY 1990 approximately 900 scientists and engineers performed experiments at these user facilities.

Recent legislation such as the Stevenson-Wydler Act, the Bayh-Dole Act, and the National Competitiveness Technology Transfer Act has prompted the DOE to incorporate technology transfer as a major mission and to facilitate cooperative interactions at its laboratories through the establishment of Collaborative Research and Development Agreement (CRADA) policies. Increased cooperation among industry, universities, and government laboratories has been specifically cited in several major scientific studies, including the two MS&E reports mentioned earlier, as essential elements to improving the nations competitive position.

User Fees

Recently the question has been raised as to whether the current policies for charging users should be changed. As mentioned above, the current DOE policy is to charge proprietary users only and to allow free access to qualified users who publish their results. I would strongly encourage that the current policies not be changed for the reasons mentioned below.

Beginning with the 1979 DOE user facility initiative and continuing through to the 1989 National Competitiveness Technology Transfer Act, the mood of the scientific community and the Congress appears to be one of encouraging and stimulating cooperative interactions among industry, universities, and government

laboratories. Introduction of the present policy in the late 1970s sharply increased this trend, and any move to increase or broaden charges to users would sharply decrease it. R&D partnership between national laboratories and industry are vital in meeting the challenges of intense international competition for new technology leadership. Assessing a user fee for nonproprietary industrial use would seriously damage the fragile but growing relationships between industry and the DOE national laboratories that the CRADAs are trying to enhance.

Since most university and many industry researchers are federally funded, assessing a user fee would simply shift federal dollars from one department of government to another, losing administrative costs en route.

New DOE initiatives to assist in improving the nation's educational system would be suppressed by imposition of user fees. Many graduate students depend on access to user facilities for their thesis research and many newly initiated educational programs for undergraduates and high school students also utilize these facilities.

Sharing unique, expensive equipment at user facilities leverages the national investment in science, promotes scientific exchange and technology transfer, and stimulates multi-institutional, multidisciplinary R&D.

APPENDIX A

Recent External Reviews, Workshops, and NSCANS Meetings

Safety Reviews

MMES Independent Review Committee	January 1989
MMES Research Reactor Independent Review Committee	June 1989
ORNL Research Reactor Independent Review Committee	October 1989
ACNFS Subcommittee Review	January 1990
ORNL Research Reactor Independent Review Committee	March 1990
ACNFS Review	May 1990
ORNL Research Reactor Independent Review Committee	August 1990
ORNL Research Reactor Independent Review Committee	January 1991

DOE Programmatic Reviews

DCES Review	April 1989
NE-ER Review	May 1990

Quality Assurance Reviews

Milloway-Manning Group QA Review	March 1989
Quality Review of ANS by DOE-EH	October 1989
Milloway-Manning Group QA Review	January 1990
MMES Corporate Audit	July 1990

User/Scientific Community Reviews

NSCANS Independent Sources Group Review	January 1989
NSCANS Executive Committee Review	March 1989
NSCANS Meeting	June 1989
ANS Site and Facility Planning Workshop	October 1989
NSCANS Executive Committee Review	April 1990
NSCANS Meeting	June 1990
ANS Materials Irradiation Facilities Workshop	December 1990

Technical Reviews/Workshops

ANS Thermal-Hydraulic (Lahey) Review	March 1990
International Workshop on Cold Neutron Sources	March 1990
ANS CPBT Workshop	February 1990
ANS Reactor Cooling System Workshop	February 1990
ANS Reactor Containment Workshop	August 1990
Neutronics Review	January 1991

APPENDIX B

Recent History of the Advanced Neutron Source

1984	ORNL begins preconceptual design using internal funds
1984	Major Materials Facilities Committee of the National Research Council recommends Advanced Photon and Advanced Neutron Sources as the two highest national priorities for new materials facilities (Seitz-Eastman report)
1984	ORNL begins detailed consultation with the scientific community with a workshop on instrumentation for the ANS
1984	Shelter Island Workshop affirms the need for a new, high-flux neutron source
1985	Gaithersberg Workshop examines neutron source concepts and scientific needs
1986	National Steering Committee for the Advanced Neutron Source (NSCANS) formed under the Chairmanship of Dr. John J. Rush
1986	$2.5M in FY-1987 DOE budget for the "Advanced Steady State Research Reactor at Oak Ridge"
1987	$7.7M written into FY-1988 DOE budget for the ANS (DOE request was $3.0M)
1988	$8.7M written into FY-1989 DOE budget for the ANS (DOE request was $3.7M)
1989	$9.5M written into FY-1990 DOE bydget for the ANS (DOE request was $4.5M)
1990	$12M written into FY-1991 DOE budget for the ANS (DOE request was $4.5M)
1991	President's budget request for the ANS is $24.6M (adequate to remain on schedule)

Mrs. LLOYD. Thank you very much, Dr. Appleton. When do you think that we can move to the construction phase?

Dr. APPLETON. I would very much like to see that to be a 1993 line item.

Mrs. LLOYD. I certainly share your convictions. We have been very concerned about getting the restart of HFIR and what it has meant. What are the limiting factors as we look at HFIR, our structural weakness and then the metal embrittlement that was involved?

Dr. APPLETON. Well, HFIR is, as you know, a reactor that is 30 years old. Many of the problems that we are seeing in HFIR, such as the reactor vessel embrittlement, were predicted. It is just that some of those happened more quickly than we had anticipated. At the current time, we think that HFIR has a useful lifetime of about ten years, which will just about coincide with the time the Advanced Neutron Source will come on line as a project.

What I think is really important about the way the Advanced Neutron Source is being built is that this is the first time a research reactor has been built with the safety and the science integrated together. So what we will have is not only a much more usable reactor for researchers, but a much safer reactor for future operations.

Mrs. LLOYD. Our material science program is going to be in pretty bad shape if we don't have ANS operable about the turn of the century, will it not?

Dr. APPLETON. Yes. I think that is a very good statement. I think both the photons that you have heard about and the neutrons that we have heard about are every year turning out to be a much more important element in the material science area.

The reason for that is that if you look at the advances that have occurred in the materials, it is because we have been able to understand the microscopic property of materials and relate those to the macroscopic behavior. That requires advanced techniques, such as the photons and the neutrons.

Mrs. LLOYD. Well, as your representative, I can tell you that I am proud of the work that you are doing. Certainly, this committee is very supportive of the work that is being done on all the advanced reactors.

Dr. Marx and Dr. Moncton, I would like for you to compare and contrast the capabilities of ALS and APS in terms of their application and different kinds of research.

Dr. MARX. Let me start. They are very complementary facilities in that the Advanced Light Source provides photons of longer wave lengths than does the Advance Photon Source. These longer wave photons don't penetrate as deeply into a sample. So we focus primarily on surface properties.

Also, in the field of chemistry—on gas phase chemistry in the dilute phase, if you have a very dilute chemical sample with an intense beam of the X-rays that the Advanced Light Source produces, you could study their microscopic properties.

So it is a difference in penetrating power of the X-rays that drives the different kinds of scientific research that will be done.

Mrs. LLOYD. Dr. Moncton.

Dr. MONCTON. Maybe I could just add to that. In addition to the difference in penetrating power, the wave length difference in the case of the ALS, the wave lengths are considerably longer in the ten to thousand angstrom range whereas the APS, the wavelengths are in the 1 angstrom range.

The longer wavelength or lower energy photons provided by the ALS are matched to the energy levels associated with electronic transitions in atoms. So the spectroscopy of the materials, the electronic structure, which is one of the important parts of that scientific agenda; whereas at the Advanced Photon Source, the short wavelength X-rays are matched to the spacing between atoms and solids and the geometric structure of the matter is more the focus of our research and understanding how it is that atoms are geometrically arranged in matter.

Mrs. LLOYD. I would like for you all to contrast the capability of the light and the neutron sources.

Do they complement each other, and if so, how do they complement each other?

Dr. MONCTON. Maybe I could add a few remarks. I started my career as a neutron scatterer. I probably published half of my scientific publications with neutrons and the other half with X-rays.

In fact, because we are talking about neutrons, whose wavelength is on the order of the distance between atoms— Angstrom X-rays and Angstrom wavelength neutrons, the two probes share a great deal of similarity in the kinds of things that they do. They are often found doing the kind of geometrical structure studies that I was speaking about.

However, neutrons and X-rays are quite different in terms of the way they interact with matter. Neutrons scatter much more strongly from the magnetic structure. Neutrons penetrate much deeply into matter. X-rays scatter much more strongly from the electronic structure. So they are very complementary in terms of the information that they reveal, with each having strength where perhaps the other is weake and vice versa.

One thing that is very important about neutrons and is very hard to do with X-rays is to study the dynamical properties of matter because neutrons have a relatively low energy on the order of milli-electron volts whereas X-rays have many kilovolts of energy. So it is possible to ascertain more about the energy structure of materials, using neutrons than it is with X-rays.

Mrs. LLOYD. Dr. Appleton.

Dr. APPLETON. Dr. Moncton gave a very good summary of the characteristics. I might just comment on some of the things that are important in the neutron area that I see in the near future.

As I indicated, we have—this year, we are going to establish a line using the penetrating power of neutrons to look at residual stress in machine parts. That turned out to be extremely important in an area such as ceramic where often when you machine ceramic, you can't tell what the stress properties of that ceramic are unless you look in depth inside of the material. So neutrons are particularly well suited for that.

The other area that Dave mentioned is that neutrons are particularly sensitive to light atoms relative to X-rays. X-have an increase scattering from heavy atoms whereas neutrons are very sen-

sitive to light atoms such as hydrogen and carbon and oxygen. If you look at the plastics in industry and many of the materials in this room are synthetics that are made from polymers and plastics. Industry is finding out more and more that they are able to really characterize and actually devise new plastics by using neutrons to look at the behavior of the light atoms.

So I concur that they are very complementary tools. Both have an important to play.

Mrs. LLOYD. Thank you. Dr. Marx.

Dr. MARX. Well, you have heard two excellent discussions of the complementary between these two probes. So I probably have very little to add to this.

Dr. MONCTON. I think there is one thing worth emphasizing. That is that we have talked a lot about the microscopic properties at the atomic level or at the level of near neighbor distances.

But one of the most exciting things that I think is happening in neutron scattering, as well as in X-ray techniques at both the longer wavelength and the short wavelength are the development of imaging technologies, getting at structural elements on a length scale going from the microscopic up to the macroscopic, and crossing through the regimes of the micron length scale, which is so important to the structure of many materials which are important technologically, like catalysts, for example.

So there are new imaging technologies that are emerging in each of neutron and soft X-ray, as well as hard X-ray technologies, which should provide some very exciting pictures of the structures of materials at the microscopic level and be of tremendous use to the researchers in those fields.

Mrs. LLOYD. Thank you. Mr. Morrison.

Mr. MORRISON. Thank you, Madame Chairwoman. I would like to state for the record that there is one other neutron source that hasn't been mentioned—if we don't read the obituaries and believe them on the fast flux test facility. There, too, a new reactor, I might add, that would last well into the next century.

I want to explore something also that I think is vitally important. I admit that I don't really have a good handle on it. That is the user's fee argument.

I have heard virtually everyone saying that somewhere there is magical line, I detect on which you can ask industry and a host of others to invest in using facilities, but that the user's fee as proposed now goes beyond that line, crosses it and is counterproductive. I would like a little more deliberation on this for the record and for our purposes on the committee.

Dr. APPLETON. I could give you some of my views. Of course, there are user fees now that are for proprietary use to industry.

If you look at the other possibilities for user fees for things that are now not charged, that would probably be a counter-productive move simply because most of the other use is by industry that is funded through the small business incentive research program.

So that is Federal funding, or through the university, which is Federal funding. If you did charge a user fee, it would simply be taking Federal money from one department, putting it into another and you would lose the administrative cost in the transfer.

If you tried to increase the fees to industry to make up the difference or to charge them a higher fee for work that they were willing to publish, I think you would simply drive them away, adversely effect technology transfer, and they probably would buy an airline ticket and go to Europe and use the ILL.

So I think for a lot of those reasons that the proposals for charging universal user fees is just not a good idea.

Mr. MORRISON. Other comments on the same framework?

Dr. MARX. Yes. I think it is important to recognize that industry does, and of course, thinks they do invest a great deal in these facilities as they now stand. They provide large amounts of equipment that they not only use but are made available to all the other users at the facilities.

For example, university researchers can get access to the equipment that industry builds for these facilities. Industry also stations a number of people at these facilities. So they supplement the intellectual capability. They supplement the people who could help in solving problems and getting work done. So they already feel like they are investing a great deal in the facilities.

My concern is if we asked them to pay significant fees, it will just drive them away. They will just feel that it is no longer cost effective. The research that they do at these facilities has to be done.

Eventually, if industry isn't doing them, university researchers and other researchers will be looking to do it and then coming back to the Federal Government for funding.

So I am afraid it is not going to bring in substantial new revenues for the Federal Government. It will drive away a strong component of research at these facilities and dilute the kind of collaborations that are so important to these facilities.

Dr. MONCTON. I think it is important to keep in mind two words—partnership and reciprocity. The partnership idea has been alluded to by a number of people. Although it is not clear often where that—and I can see where the concern is in your mind—where that line ought to be.

Those of us that are very familiar with the sociology in the field have a good feeling for where that line is. That line is positioned now at such a point where the various partners in this endeavor are contributing in an approximately equal fashion.

They both have essentially equal standing in the work. If one were to impose full cost recovery fees, then you would be putting the full burden of this basic research which benefits the entire country, onto the individual industrial researcher. So you would be off-loading the entire burden of that research. You would simply, as Bill stated, get less of that research because there is only a fixed industrial research level available.

The reciprocity issue, I think, should also be considered. If you charge industry—well, industry is making a substantial investment in beam lines and their equipment, and making that equipment available to other researchers. The reciprocity principle would lead to them, perhaps, instituting charges. In some cases, those beam lines are being used by researchers funded by the Government. So the Government might be, in fact, paying fees to industry for using their facilities.

Mr. MORRISON. Oh, yes, but it is charged to a different department, which, unfortunately, makes the point.

Dr. MONCTON. The reciprocity, I think, ought to be considered with respect to the foreign facilities.

Mr. MORRISON. I think where we would, here on the Science and Technology Committee, draw the line is probably very close to where you might see that it would be correct, I think. Probably the Department has been pushed by OMB to draw the line somewhere else. That makes it tough for us to wrestle with this and find the proper answer.

My presumption is that most of the people who are using your facilities are developing a process of their own. If it works for them, we will eventually have to duplicate the facilities, but we don't want to make that investment until they are sure of a product that they can produce. Is that an accurate judgement?

Dr. MONCTON. One would hope that someday much smaller facilities could be built, but in most cases, as we understand the technology today, we wouldn't expect an IBM or an Exxon to be building a facility of the size of the Advanced Photon Source.

In certain specific cases, like in the application of X-ray lithography or in the applications or coronary angiography, it is possible to build much smaller synchrotron sources for those purposes. One might see smaller, individual sources being developed. I think it is going to take some time before accelerator technology advances. One would hope we would actually see that day where we would have smaller scale facilities. They would proliferate within the research establishment since they would be more conveniently accessed.

Mrs. LLOYD. Or potentially we might see some additional facilities built that were designed exclusively for processing, with the costs shared by a number of manufactures.

Dr. MONCTON. Certainly, that would most likely be the case in the lithography area. You will see the first example of that, and then perhaps later in the medical area.

Dr. APPLETON. I might just add a comment on that. The neutrons are a much different problem because of the difficulty of running a reactor, as you well know with the FFTF. So that will probably always be a facility that is relegated and in a user status because of the regulatory problems with the reactor.

Mr. MORRISON. That we would hope to work on the regulatory end. Our problem with FFTF is not with the neutrons, it is with the Department of Energy, I might add.

Thank you, Madame Chairwoman.

Mrs. LLOYD. Well put, Mr. Morrison.

Mr. Fawell?

Mr. FAWELL. Thank you, Madame Chairwoman. My question was in regard to the reciprocity to which you have already given an answer. I am amazed at the $200 million being the contribution for the users and their respective beam line access. When a partnership gains that access, what are the ownership rights or tenant rights? I am not sure it would be likened to one or the other, and how long would they have these kinds of rights?

Dr. MONCTON. They would construct their beam line, which has a well-defined point of interface with the accelerator facility. So it is

very clear what the Department of Energy's facility consists of and then what the beam line that would be owned by the outside group consists of. That is a very well-defined piece of capital equipment. They, of course, would own that.

If they were to terminate their research program at some time in the future, they would remove that and that equipment would belong to them.

Now as far as that process is concerned, when our proposals are approved for access to the facility, then they will be subject to a yearly review. We have guaranteed them a three-year period, during which they will have annual reviews. At the end of that three-year period, a decision will be made whether to renew or not.

If they are not renewed, then they will be given two years to terminate their program at the minimum under the worst circumstances. Where a review panel judge their research to be substandard, a group would have, by virtue of having committed something on the order of $10 million or perhaps more, to that facility, they would have access for this five-year period.

Mr. FAWELL. Would they have exclusive access?

Dr. MONCTON. The system which is in place at the National Synchrotron Light Source, which we believe has been a great success is that 25 percent of the time on their facility would be made available to the general community. It would be awarded to individual investigators on a basis of merit determined by review panel. This is one way in which the community pays for access which I think should be taken into consideration when one thinks of charging user fees. We have already asked them to tithe to the extent of 25 percent of their beam time. That has been a very healthy thing for the community because it has enabled many new researchers an entry level into the field.

Mr. FAWELL. They might even have money coming from the Government when it is all done, with their creditors.

Thank you.

Mrs. LLOYD. Thank you, Mr. Fawell.

All of our testimony has been excellent. We appreciate all of our witnesses today. Again, I want to thank the staff for their excellent work in preparation for our hearing today. I thank all of you involved with this hearing.

If there are no further comments, the committee stands adjourned.

[Whereupon, at 4:28 p.m., the subcommittee adjourned, to reconvene at the call of the Chair.]

APPENDIX I

OPENING STATEMENT

HON. MARILYN LLOYD

BASIC ENERGY SCIENCE HEARING

MARCH 19, 1991

I WOULD LIKE TO TAKE THIS OPPORTUNITY TO WELCOME THE WITNESSES BEFORE THE ENERGY SUBCOMMITTEE. WHILE TODAY'S HEARING WILL EXAMINE THE FY 1992 BUDGET FOR BASIC ENERGY SCIENCES AND RELATED AREAS, I BELIEVE IT IS IMPORTANT THAT WE EXAMINE THE ISSUES RELATED TO THESE PROGRAMS IN A LONG TERM CONTEXT. IT IS THE SUBCOMMITTEE'S INTENTION THAT THIS HEARING WILL PROVIDE THE BASIS FOR DEVELOPING A MULTI-YEAR AUTHORIZATION BILL FOR THOSE PROGRAMS.

WE SEE SEVERAL MAJOR CHANGES UNDERWAY INVOLVING A NATIONAL INITIATIVE FOR MATERIALS SCIENCES, THE HIGH PERFORMANCE COMPUTER INITIATIVE, THE FUTURE OF UNIVERSITY RESEARCH REACTORS AND THE CONSTRUCTION OF LARGE, WORLD CLASS USER FACILITIES.

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THESE CHANGES WILL HELP SHAPE NOT ONLY THE FUTURE OF THE BASIC ENERGY SCIENCES PROGRAMS BUT WILL ALSO HAVE A SIGNIFICANT IMPACT ON THE FUTURE EVOLUTION OF THE NATIONAL LABORATORIES. FOR THESE REASONS IT IS IMPORTANT THAT WE LOOK AT THE PROGRAMS WITH A LONG TERM PERSPECTIVE. FAILURE TO UNDERSTAND THESE CHANGES MAY LEAD US TO VIEW THESE AS THREATS AND TO REACT ACCORDINGLY. HOWEVER, IF WE UNDERSTAND THESE CHANGES IN THEIR BROADEST CONTEXT THEN I BELIEVE WE CAN SEIZE THE OPPORTUNITIES THEY PRESENT.

WE WOULD ASK OUR WITNESSES TO HELP US UNDERSTAND THESE CHANGES THAT ARE UNDERWAY. WE WILL SEEK THE BENEFIT OF THEIR EXPERIENCE AND THE PERSPECTIVE THEY BRING. I DON'T HAVE TO REMIND YOU THAT FINANCIAL PRESSURE NECESSITATES THAT WE MAKE THE MOST OF TH' RESOURCES AVAILABLE TO US TO FURTHER LONG TE' NATIONAL INTERESTS.

WE WILL LISTEN WITH GREAT INTEREST TO LEARN FROM YOUR EXPERTISE SO AS TO MAKE THE MOST OF THE RESOURCES AVAILABLE FOR THESE PROGRAMS.

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SCIENCE RESEARCH AND TECHNOLOGY
SELECT COMMITTEE ON AGING

U.S. REP. JERRY F. COSTELLO

COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

SUBCOMMITTEE ON ENERGY

HEARING ON AUTHORIZATION OF THE DEPARTMENT OF ENERGY'S FY 1992 BUDGET REQUEST FOR BASIC ENERGY SCIENCES

MARCH 19, 1991

Madam Chairman, I thank you for calling this hearing on DOE's budget for the Basic Energy Sciences program. As always, I am anticipating some enlightening testimony from our witnesses.

Today we will look at the Basic Energy Sciences three main programs: the materials sciences program, user facilities and university reactors, and nuclear engineering education. The respective panels will hopefully discuss the status of each of these programs.

As you know Madam Chairman, I have stated in the past that we must begin to find ways to improve the math and science education in this country. Once again your hard work and dedication has gathered us here today to take a in depth look at how we can continue to improve our endeavors in this area.

Madame Chairman, thank you again for calling this hearing.

THIS STATIONERY PRINTED ON PAPER MADE OF RECYCLED FIBERS

OPENING REMARKS
THE HONORABLE TERRY L. BRUCE
ENERGY SUBCOMMITTEE HEARING
BASIC ENERGY SCIENCES
March 19, 1991

THANK YOU, MADAME CHAIRWOMAN.

I WOULD LIKE TO TAKE THIS OPPORTUNITY TO WELCOME DR. BARCLAY JONES FROM THE NUCLEAR ENGINEERING DEPARTMENT AT THE UNIVERSITY OF ILLINOIS AT CHAMPAIGN-URBANA IN MY HOME DISTRICT. WE ARE ALL VERY PROUD OF THE WORK BEING DONE AT THE UNIVERSITY OF ILLINOIS AS IT STANDS OUT AS ONE OF THE OUTSTANDING RESEARCH UNIVERSITIES IN THE COUNTRY.

FURTHERMORE, I WOULD LIKE TO WELCOME TWO OTHER FELLOW ILLINOISANS REPRESENTING ARGONNE NATIONAL LABORATORIES, DR. DAVID MONCTON AND DR. FRANK FRADIN. THESE THREE GENTLEMEN REPRESENT TO THE INCREDIBLE ACTIVITIES HAPPENING IN THE WORLD OF SCIENCE AND TECHNOLOGY; THEY REPRESENT THE RESEARCH HAPPENING IN THE STATE OF ILLINOIS. WE ARE GLAD TO HAVE THEM WITH US TODAY.

I LOOK FORWARD TO DISCUSSING THE DEPARTMENT OF ENERGY'S BASIC ENERGY SCIENCES BUDGET REQUEST FOR FISCAL YEAR 1992. THE FOUR KEY AREAS OF THE PROGRAM, NAMELY, THE MATERIALS SCIENCES PROGRAM, USER FACILITIES, UNIVERSITY RESEARCH REACTORS, AND NUCLEAR ENGINEERING EDUCATION ARE ALL OF INTEREST AND IMPORTANCE NOT ONLY TO THE SCIENCE AND EDUCATIONAL COMMUNITIES, BUT TO THE NATION AS A WHOLE.

THE IMPORTANCE OF FUNDING THIS RESEARCH APPROPRIATELY CANNOT BE OVERLOOKED. AS I HAVE SAID ON MANY OCCASIONS, THE SCIENCE AND TECHNOLOGY DEVELOPMENT OF THIS COUNTRY FORMS THE BASE FOR THIS

NATION'S ECONOMIC HEALTH AND WELFARE. EVEN WITH THE CURRENT BUDGET CONSTRAINTS, THE SCIENTIFIC, AND HENCE, ECONOMIC INFRASTRUCTURE OF THIS NATION CANNOT BE FORGOTTEN.

THANK YOU, MADAME CHAIRWOMAN.

APPENDIX II

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American College of Nuclear Physicians
The Society of Nuclear Medicine

To Whom it May Concern:

I respectfully submit this testimony for the record. It would also be very much appreciated if this statement were distributed to the Committee Members and interested parties, if convenient.

Thank you for your attention and consideration. Feel free to contact me if you have any questions or require additional information.

Sincerely,

Kristen D.W. Morris
Director of Government Relations

ACNP 1101 Connecticut Avenue, N.W. • Suite 700 • Washington, D.C. 20036 SNM
202-429-5120
American College of Nuclear Physicians
The Society of Nuclear Medicine

STATEMENT OF

THE SOCIETY OF NUCLEAR MEDICINE

and

AMERICAN COLLEGE OF NUCLEAR PHYSICIANS

concerning the

DEPARTMENT OF ENERGY'S FISCAL YEAR 1992 BUDGET

for the

MEDICAL APPLICATIONS PROGRAM

submitted to the

HOUSE OF REPRESENTATIVES

SCIENCE, SPACE AND TECHNOLOGY SUBCOMMITTEE ON

ENERGY, RESEARCH AND DEVELOPMENT

March 19, 1991

The Society of Nuclear Medicine (Society) and the American College of Nuclear Physicians (College) are pleased to offer the following statement regarding the Department of Energy's Fiscal Year (FY) 1992 budget. Together, the Society and the College represent over 14,000 physicians, physicists, chemists, radiopharmacists, technologists and other professionals engaged in nuclear medicine research and clinical practice.

SUMMARY

The Administration's FY 1992 budget proposal seeks $33,900,000 for the Department of Energy (DOE) Medical Applications Program. Over the past decade, the budget for the DOE Medical Applications Program has been flat or declining with substantial appropriations earmarked for special projects that do not enhance or contribute to the overall nuclear medicine research program. The College and Society recommend a funding level of $42,135,000 or an annual increase of 6% from FY 1989.

The College and Society appreciate the severe budget constraints that the Congress and your Subcommittee must consider in addressing FY 1992 budget needs. However, previous research activities resulting from the DOE's Medical Applications Program, designed to enhance the applications of both radioactive and stable isotopes, have contributed significantly to the health care delivery system in the United States. In order to continue the progress and momentum achieved in the field of nuclear medicine, it is imperative that funding for research efforts be increased.

The declining financial support of research exacerbates the problem of the lack of national resources (for example, accelerators and reactors) to produce radioisotopes. In fact, in the foreseeable future, radioisotopes may only be available from foreign sources. Of note, there is no domestic supply of a radioisotope critical to nuclear medicine (molybdenum-99) and it is expected that DOE labs will cease to produce accelerator isotopes within the next five years.

Last year Capt. William Briner, (Ret.), Chairman of the Government Relations Committee for the Society, testified before this committee and illustrated these problems. "Of immediate interest is the current limitation on the supply of this critical radioisotope [molybdenum-99]... More than 90 percent of all nuclear medicine diagnostic procedures in the U.S. are performed with this material...More than 10,000,000 nuclear medicine studies are performed in the United States each year and this should not be compromised."

After the permanent shut down of the Cintichem Reactor in Tuxedo, New York, the sole source for MO-99 became the Nordion, Inc. (formerly AECL) Chalk River, Ontario, Canada reactor. In January 1991, this reactor was forced to shut down due to complications. The supply of this critical material was interrupted for days and shortages in the medically important isotopes, iodine-131 and phosphorous-32, still persist. The U.S. has no recourse but to rely on a Canada-based backup reactor until further notice.

The College and the Society are currently working with the DOE to address the need for accelerator produced isotopes. The ACNP and SNM have developed a proposal together with the DOE for a National Biomedical Tracer Facility (NBTF). The NBTF will be a high energy accelerator dedicated to training in the radiologic sciences, biomedical research, and isotope production. This proposal will be submitted to the Congress, the Secretary of DOE and the President of the United States for consideration within the coming weeks.

However, the very critical problem of reactor produced isotopes is a far larger issue that must be addressed at an increased level. It would be uneconomical to dedicate a nuclear reactor for biomedical purposes. Therefore, we urge this Committee and the Congress to address this need.

The College and the Society have three primary goals:

1. Increase and protect the DOE Medical Applications Program.

2. Establish a National Biomedical Tracer Facility for training, education, research, and production purposes.

3. Direct the Hanford Fast Flux Test Facility to become a national production center for molybdenum-99 (Mo-99).

NUCLEAR MEDICINE TODAY

In a typical nuclear medicine procedure, a tracer chemical substance is administered in the form of a radiopharmaceutical. The diagnostic use of a radiopharmaceutical is based upon the ability of the imageable or traceable agent to measure and evaluate organ function or a disease process. Certain radioactive drugs are designed to concentrate only in abnormal tissue such as cancer cells or compromised heart muscle. The transit is recorded by instrumentation which images the distribution of the radioactive preparation in the body. Data derived from the examination may also be processed by computer, producing improved images and quantitative information about organ function. Depending on the degree of specific localization and the physical and biologic behavior of radioactive labels, radiopharmaceuticals can also be used therapeutically for certain conditions.

Diagnostic in vitro examinations encompass certain tests (radioimmunoassay) in which a sample of body fluid is mixed with a radioactive reagent. These tests are used to determine the presence of cancer antigens, the precise concentration of various hormones, vitamins and drugs and to identify pollutants or other toxic materials in the environment. Radioimmunoassay techniques permit early discovery of tumors and metastases before they become clinically evident.

THE ROLE OF NUCLEAR MEDICINE

The Society and the College believe that nuclear medicine procedures enhance the diagnostic process by reducing total health care costs, decreasing the patient's length of stay as well as the patient's suffering by rapidly directing patient treatment. In addition, nuclear medicine procedures often provide more useful information about the patient's problems than other data available from alternative diagnostic modalities, many of which are much more costly. One in three of all hospitalized patients in the U. S. are treated with or have a diagnostic test that utilizes some form of nuclear medicine. Nuclear medicine studies provide a "snapshot" of the metabolic activity at the time of the image, as opposed to other imaging procedures, such as radiography, which reveal only anatomic information.

Nuclear medicine techniques are especially versatile for basic research in the chemical, biological and physical sciences. Since techniques are similar, data in these areas are easily expanded into clinical research, allowing rapid application of information from the research laboratory to hospital practice. DOE supported research is conducted in several areas: the development of radiolabeled tracers, the refinement of PET (Positron Emission Tomography) and SPECT (Single Photon Emission Computed Tomography), the enhancement of imaging instrumentation and clinical feasibility studies of innovative nuclear medicine procedures.

The following are a few of many such applications, demonstrating the importance of a continuing high level of research:

CARDIAC NUCLEAR IMAGING

One of the most dramatic examples of the rapid transfer of research developments to the hospital is the non-invasive study of the heart. According to American Heart Association statistics, as many as 1,500,000 Americans will have a heart attack this year and more than 500,000 will die as a result. The number of deaths from heart and blood pressure diseases far exceeds the number of deaths from all cancers. In addition, the cost of cardiovascular disease in 1991 is estimated by the American Hospital Association at $101.3 billion. This figure includes the cost of physician and nursing services, hospital and nursing home services, the cost of medications and lost productivity resulting from disability. Early identification of persons at risk of heart attack had previously been difficult. Nuclear diagnostic techniques are significantly more sensitive and less risky in identifying individuals with coronary artery disease than other diagnostic methods such as electrocardiographic stress testing. Studies from a number of PET centers note a very high sensitivity and specificity for PET in the diagnosis and evaluation of the severity of coronary artery disease.

PET is also accurate in determining myocardial viability. In patients with previous infarction, the determination of myocardial viability is important prior to revascularization. No other methods have been as accurate as PET in defining myocardial viability. It is estimated that 10-15% of patients undergoing revascularization may not benefit from the procedure. The economic impact of a method such as PET for identifying these patients is apparent.

DOE-sponsored research is also directed at the development and refinement of SPECT, similar in technology to PET, but one which is less expensive and can be readily available in most nuclear medicine departments. The importance and cost-effectiveness in the use of SPECT imaging is demonstrated by the patient who presents with chest pain and signs of a myocardial infarction, requiring hospitalization in the coronary care unit (CCU). The use of technetium-99m labeled isonitrile (which can be chelated within the laboratory of the nuclear medicine department and is available for emergency care) with SPECT imaging is a valuable tool in the triage of the cardiac patient and determining the short and long term care of the patient.

SPECT imaging is also used predominantly in screening for myocardial perfusion with radiothallium. This procedure constitutes 25-30% of the nuclear medicine laboratory activities. Treadmill exercise is generally used to produce stress. However, pharmacologic intervention (the use of the drugs Persantine or Adenosine) is being used to produce simulated cardiac stress. Parenteral Persantine was recently approved by the Food and Drug Administration (FDA); its availability will allow studies to be performed on patients who are currently considered poor candidates for the treadmill.

CANCER PATIENT EVALUATION

The major emphasis of nuclear medicine in oncology has shifted from the therapeutic application of radioisotopes to the use of enhanced imaging modalities which allow earlier detection and improved staging of cancers. In addition, there is growing use of nuclear medicine in monitoring the therapy of cancer and early discovery of recurrent or metastasized cancers. This information allows the clinician to continue or modify treatment. Among the more serious problems in cancer chemotherapy are the side effects produced by anti-cancer agents. Such effects can often be more efficiently monitored through the use of nuclear medicine procedures. For example, certain chemotherapeutic agents can adversely affect cardiac tissue. Nuclear medicine methods provide a guide to therapy whereby the level of drug toxicity and the possible drug induced heart failure can be avoided.

Despite this progress, present technology cannot successfully identify very small growths and often cannot determine their nature. Therefore, these techniques need to be improved by development of more specific radioactive drugs, by exploration of more sophisticated immunologic and biochemical methodology and by development of instruments with enhanced spatial resolution (such as that offered by PET and SPECT).

Research with radiolabled monoclonal antibodies is an example of a promising new approach that is being pursued. Labeled monoclonal antibodies utilize the specificity of an antibody to a tumor as a way of localizing the dose. With the advent of monoclonal antibody technology particular attention has been given to the therapeutic isotopes. Several radioisotopes have been identified for potential use in this area of nuclear medicine. As radiolabeled monoclonal antibodies for melanoma, colorectal cancer, prostate cancer and lung cancer become clinically available, they will be important in use as a therapeutic modality for inflammatory arthritis and skeletal cancer metastases. Therefore, as the level of investigation of the monoclonal antibody technology and radioisotope use escalates, the production of and access to these radioisotopes will have to be addressed.

NEUROLOGIC APPLICATION

The National Advisory Neurologic and Communicative Disorders and Stroke Council have deemed the 1990's as the Decade of the Brain.

A significant contribution of the DOE - sponsored research is the investigation of the chemistry and metabolic patterns of the brain and central nervous system. PET is the first imaging technique that illustrates the metabolic activity in the various regions of the brain.

PET studies have clearly provided important information in the clinical management of patients with seizure disorders who are refractory to anticonvulsant therapy. Invasive techniques such as the placement of subdural strip electrodes and stereotactically - placed depth electrodes are typically used to evaluate these patients. These invasive techniques are costly and involve risk. The benefit of PET is that it allows the evaluation of the patient without the need for invasive monitoring. The findings on the PET scan demonstrate good correlation with the pathologic findings.

PET scanning is also useful in several aspects of the management of patients with primary brain tumors. PET scans are the only studies able to distinguish recurrent tumor from necrosis as a result of radiation therapy. PET scans are also useful in the initial staging of the tumor and guiding appropriate therapy.

DOE-sponsored investigators are also using PET scans in the study of dementias, stroke, epilepsy and neuropsychiatric disorders. With its advanced specificity, PET improves the clinician's ability to differentiate in his diagnosis between Alzheimer's, multiple infarct dementia, Huntington's and Parkinson's, to separate these diseases from the normal aging process and to remove confounding issues of therapies applied to patients that are heterogenous mixtures of different diseases. In addition, PET imaging is not only able to determine abnormal blood flow patterns in the brains of Alzheimer's patients, but is also capable of detecting this debilitating disease in its earlier mild and moderate stages.

In addition, for neuro-SPECT imaging, lipophilic gamma-emitting agents have been developed which diffuse readily into the brain after intravenous injection. These lipophilic complexes reflect regional differences in cerebral blood flow. Therefore, cerebrovascular disease can accurately be diagnosed, as can other diseases that demonstrate alterations in regional cerebral blood flow, such as head trauma, dementias and seizure disorders, with the use of SPECT.

Other than brain tumor extent and viability, SPECT, qualitatively, is equal to PET. Both techniques have clinically comparable resolution. The most notable difference is the more accurate quantification available with the tomographic images in PET. The improvement of SPECT instrumentation and quantification would significantly increase SPECT's utility. This is a significant research opportunity which at present is underfunded.

NUCLEAR MEDICINE INSTRUMENTATION

Progress in nuclear medicine research and the eventual application of research results in the clinical setting is dependent upon the refinement of existing instrumentation, the development of new technology and the availability of radioisotopes. The potential application of PET technology in the diagnosis and treatment of disease requires further refinements in its ability to resolve small structures more discreetly. In addition, since PET studies require costly, on-site cyclotrons, additional research and development is needed to design smaller less costly models so that more patients can benefit from this exciting technology. Further development of radionuclide positron emitters with half-lives of at least a few hours would relieve the dependency on immediate cyclotron production for certain applications.

Two recently approved cardiac imaging agents will increase the demand for dedicated SPECT scanners. DOE research funds could also be wisely invested in advancing the development of SPECT, which could be more readily available to nuclear medicine departments than PET.

PEER REVIEW OF PROJECTS

In order to continue the progress achieved in the field of nuclear medicine it is imperative that funding for research efforts be increased and should not be appropriated without scientific peer review. Earmarking funds for particular projects not only undermines the scientific peer review process but also is contrary to recommendations made by committees of distinguished experts whose counsel and evaluation was sought by the DOE.

CONCLUSION

The Society and College urge Congress, as well as the Department of Energy, to continue to expand its support of nuclear medicine research activities. The Administration's budget request is inadequate to sustain projected future yields.

For the past several years, the nuclear medicine community has urged increases in the DOE Medical Applications program. A substantial and steady infusion of funds is necessary to counter the previous stagnant funding levels and to facilitate promising research which is based on competitive scientific review. Our recommendation for a $5.3 million increase over 1991 funding for the program in FY 1992 will ensure support of vital research activities in nuclear medicine.

We want to assure the Committee that the nuclear medicine community will continue to work closely with the Department of Energy in the development of its research programs and the identification of opportunities in diagnostic imaging and therapy. The exchange of views and knowledge between DOE officials and the medical community helps to assure that the greatest possible benefit is derived from the funds committed.

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March 15, 1991

The Honorable Marilyn Lloyd
Chairman, Subcommittee on Energy
Committee on Science, Space and Technology
U.S. House of Representatives
Suite 2320 Rayburn House Office Building
Washington, DC 20515

Dear Representative Lloyd:

On behalf of the American Nuclear Society, I am pleased to submit the attached statement to be included in the March 19, 1991 hearing record of your Committee.

My statement deals with the issues related to the nuclear engineering education infrastructure in the United States and ways to strengthen it in the national interest.

We appreciate the opportunity to provide written testimony on a matter of major importance to the nuclear science and technology community.

With very best regards.

Sincerely yours,

M. Jack Ohanian

MJO:dd

enclosures

cc: R. C. Liimatainen

STATEMENT

Submitted to the

Subcommittee on Energy Research and Development
Committee on Science, Space and Technology
U.S. House of Representatives

by

M. Jack Ohanian, Ph.D.

President
American Nuclear Society

Professor of Nuclear Engineering and Associate Dean
College of Engineering
University of Florida
Gainesville, FL 32611

March 19, 1991

Chairman Lloyd and members of the Committee:

I appreciate this opportunity to share with you some major concerns related to nuclear engineering education and its future ability to meet the manpower development, innovative research and related educational needs of this nation's nuclear science and technology infrastructure.

During the past decade the number of nuclear engineering Bachelor's and Master's degrees awarded continued to decline significantly. This situation is well demonstrated in Figure 1 which is based on the recently completed National Academy of Engineering/National Research Council study "U.S. Nuclear Engineering Education: Status and Prospects"[a]. Doctoral degree production has also declined, but not as dramatically, and now hovers around the 100 per year mark. During the same period the number of schools offering a nuclear engineering major declined from 44 to 39 and since the completion of the study several other schools have discontinued programs so that today there are no more than 35 remaining (in addition, there are about 15 schools offering an option only in nuclear engineering). This is in significant contrast to the 70 plus programs and options that existed in the mid-70's.

Most importantly, the just published National Energy Strategy Report[b] reflects a significant mismatch developing between supply and demand[c]: "The Department of Energy estimates that to meet its currently planned programs in such areas as environmental remediation, waste management, and new production and other advanced production reactor development, it would absorb almost half of the U.S. citizen graduates in nuclear engineering each year from 1991 to 2015, **assuming no change in 1988 graduate rates.** The Department also projects a doubling, or even trebling, of the demand for nuclear-trained engineers after the year 2000." When these requirements are considered within the context of this nation's overall manpower needs in nuclear science and technology, the potential for shortages becomes a significant concern. The National Academy study also provided supply and demand projections for newly graduated nuclear engineers. This is shown in Figure 2 and is taken directly from the study report [d]; the "U.S. civilian labor force" refers to government and industry employment. A conclusion of the report[e] is that: "The potential for increased demand is greater than the potential for increased supply, owing primarily to decreasing student populations. Significant shortages in nuclear engineers may be observed as early as the mid-1990's."

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[a] National Academy Press, Washington, D.C. 1990.
[b] First Edition, 1991/1992; February 1991.
[c] page 211 of the National Energy Strategy report.
[d] page 70 of the National Research Council report.
[e] page 71 of the National Research Council report

The key point is that university educational programs cannot be turned on and off at will and must be nurtured for the long term. It takes time to build and maintain academically sound and productive programs; and these programs are based on strong partnerships between the institution (state or private), the federal government and the industry. This nation's nuclear engineering programs were built on such partnerships and their viability depends on the continuation of these relationships. While the Department of Energy's current funding levels for fellowships and research programs provide a semblance of stability, they fall significantly short of what is needed to maintain, let alone strengthen, the capabilities of university nuclear engineering programs and to prepare them for their role in the future. There is a well-qualified and pent-up desire to solve the technical challenges ahead; for example, it is well known that for the 1990 university research awards program, the Department of Energy received many more qualified (via the peer review process) proposals than it was possible to fund.

Therefore, increased support for university-based research awarded on a competitive basis is essential; this support provides the complementary benefits of developing needed technological advances while also meeting the nation's need for highly qualified personnel in nuclear science and technology. It should also be recognized that there is a desirable synergism between graduate-level education and research. Strong graduate programs provide a positive feedback mechanism into maintaining strong undergraduate programs leading to the production of well-qualified bachelor's degree holders.

A related issue is the status of our nation's university-based research (and training) reactors. The number of licensed university-based reactors still operating today has declined from 71 in the 1970's to the current number of 37. Moreover, the remaining facilities are in major need of upgrades. This point was strongly made in the recent study by the National Academy of Engineering/National Research Council titled: "University Research Reactors in the United States--their Role and Value"[f]. The report states: "The Committee finds that U.S. university reactor facilities must be upgraded and provided with modern equipment if they are to meet their intended objectives and become world-class research and educational facilities."[g] The report further noted the broad use of these reactors in research, education and service in all aspects of nuclear science and technology. Yet they are in critical need of modernization since almost all of them were built in the late '50's and in the '60's. This modernization would impose a substantial financial burden on the host institution at a time when nuclear engineering programs are under significant financial pressures. Nevertheless, these reactors have broad applicability beyond just

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[f] National Academy Press, Washington, D.C. 1988.
[g] page 3 of the National Research Council report.

the nuclear engineering discipline (in areas such as physics, chemistry, biology, medicine, epidemiology, environmental sciences, material sciences, fluid mechanics, geology, archaeology and many others). They truly constitute an important national resource and make a substantial contribution to our nation's research capability as well as to the education of the well-qualified technical workforce that is essential to the nuclear enterprise. Moreover, because foreign research reactors are newer and yet receive about ten times the support of U.S. university research reactors, nuclear science and technology competitiveness in this country is at a serious disadvantage.

The Department of Energy has recognized this problem as stated in the National Energy Strategy Report[h]: "in the key research area of nuclear science and engineering and the related field of radiation protection and health physics, the Department of Energy will support the upgrade and expansion of the capabilities of the Nation's research and test reactors to strengthen university research capabilities and maintain state-of-the-art research facilities. This will allow investigators to accomplish basic and fundamental research and to train scientists and engineers on state-of-the-art research facilities--thereby ensuring the national resource of qualified personnel for nuclear powerplant research, design, construction, operation and regulation." While there has been Department of Energy funding for the Reactor Sharing Program and for equipment modernization, the level of funding has remained very modest and at this level cannot meet the objectives of the Department as stated here.

The American Nuclear Society[i] fully supports the funding recommendation made by the Nuclear Engineering Department Heads Organization and the National Organization of Test, Research and Training Reactors. The funding level of seventeen million dollars (eleven million dollars for research and graduate student support and six million dollars for reactor support and upgrades) for FY 92 together with the proposed FY 93 and FY 94 funds is an investment in our energy future.

Thank you for giving me this opportunity to comment, on behalf of the American Nuclear Society, about an issue that I believe merits your consideration and support--it is certainly in our national interest to maintain a strong nuclear engineering education infrastructure as we move toward the 21st Century.

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[h] page 194 of the National Energy Strategy report.

[i] The American Nuclear Society is an international, not-for-profit scientific and technical organization of more than 16,000 engineers, scientists and educators. The main objectives of the Society are the advancement of the science and engineering relating to the atomic nucleus and of allied sciences and arts.

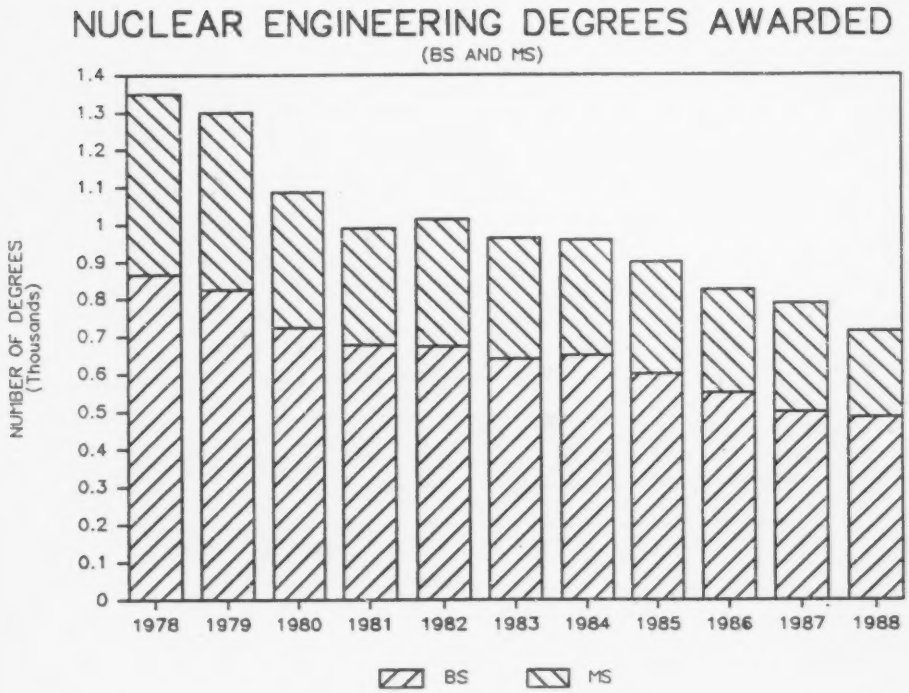

Figure 1:
This graph shows the decline in the number of nuclear engineering BS and MS degrees awarded. The number of BS degrees includes both degrees in nuclear engineering and degrees in other fields with nuclear engineering options. During the same ten-year period, the total number of engineering degrees (BS and MS) awarded increased by 51 percent.

Source: "U.S. Nuclear Engineering Education: Status and Prospects" National Academy Press, Washington, D.C. 1990

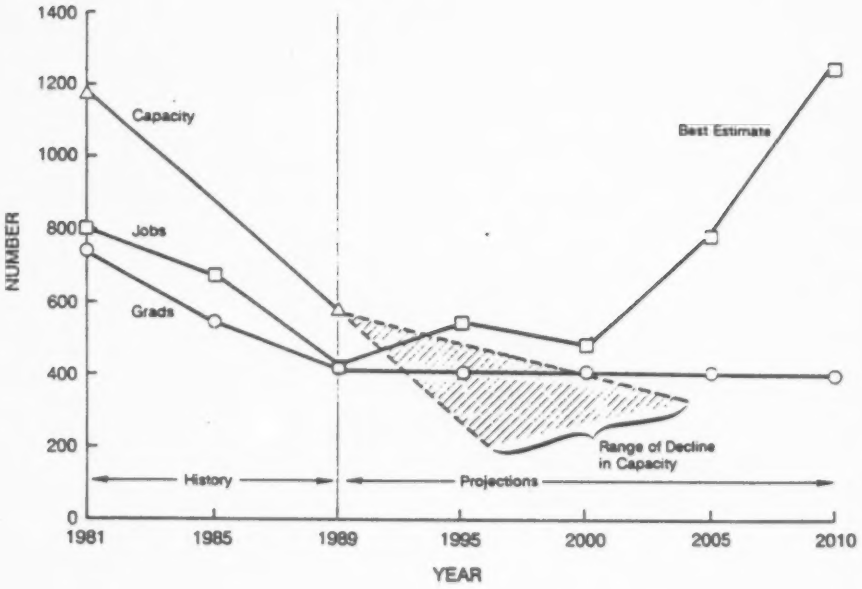

Figure 2:

Supply and demand projections for new graduate nuclear engineers in the U.S. civilian labor force.

Source: "U.S. Nuclear Engineering Education: Status and Prospects" National Academy Press, Washington, D.C. 1990

The American Society of Mechanical Engineers

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Statement of the

InterCouncil Committee on Federal R&D

of the

American Society of Mechanical Engineers

on the

Department of Energy

FY 1992 Budget Request

Submitted to the Subcommittee on Energy

of the Committee on Science, Space and Technology

U.S. House of Representatives

April 11, 1991

Madame Chairman and Members of the Subcommittee.

The InterCouncil Committee on Federal R&D of the American Society of Mechanical Engineers (ASME) is pleased to submit this statement for the record. It presents the views of several of our technical divisions on the FY 1992 DOE budget request for energy research and development programs.

It should be noted that this budget request marks the beginning of a new era in federal investment in energy R&D. The administration and the congress have opened a fresh debate on a national energy strategy. Because of the Gulf War, the national conscience has been reawakened to the need for such a strategy. Government, both at the federal and state levels, has responded with revised programs and legislative initiatives. These efforts are aimed at achieving energy security by reducing demand for foreign oil, increasing domestic production of both fossil and alternative energy resources, while seeking publically acceptable means for improving the efficient use of our energy supplies in order to conserve these resources. While the administration's proposed National Energy Strategy mainly addresses short-term actions, particularly with regard to increased usage of scarce domestic oil and natural gas reserves, the NES does recognize that global reserves of fossil fuels are finite. An expanding role of nuclear and renewable energy resources is envisioned, appropriately anticipating the long-term scenario.

Clearly, the Department of Energy's proposed $2.8 billion FY 1992 program for Energy Supply R&D must play a critical role in the effort to achieve both short-term and long-term goals. Groups within the ASME have reviewed this budget in the context of the administration's proposed National Energy Strategy and several legislative bills now under consideration by Congress. We believe that the engineering community, of which the 118,000 ASME members throughout the U. S. and abroad are a significant representation, is uniquely qualified to assist the Congress in its deliberations on the efficacy of these federal investments in energy R&D. To this end, the remainder of my comments relate to specific program areas that in our view are critical to meeting our future energy needs.

Conservation and Renewable Energy

Conservation and Renewable Energy technologies can contribute significantly to improving our national energy security and competitiveness.

The NES is unduly pessimistic regarding our ability to reduce primary energy consumption. With normal improvements in energy efficiency (Current Policy Base), consumption is expected to be 144 quads in 2030. Enhanced conservation measures under the NES will reduce this only to 120 quads. According to a DOE report, "The Potential for Renewable Energy: An Inter-Laboratory White Paper,"

enhanced conservation measures could further reduce energy consumption. Conservation research funding should be increased at a greater rate to promote this goal.

The renewable energy technologies including solar, biomass, wind, hydro, and geothermal are expected to account for only 22 quads, up moderately from Current Policy Base projections of 17 quads. The same White Paper indicates that with accelerated R&D, the renewable contribution could be considerably larger, which would stretch increasingly scarce fossil fuel reserves and develop these technologies so that they can eventually take over entirely if nuclear fission or fusion does not develop as hoped. We feel that the proposed 2% increase in the 1992 budget request for Renewable Energy over the FY 1991 allocation falls far short of what is needed to allow these technologies to provide this contribution. A specific area where the R&D budget is not commensurate with the potential benefit is thermal energy storage.

Diurnal (daily) thermal energy storage can help meet peak electrical demand without the need to construct new power plants. It is estimated that thermal storage has the potential to reduce peak building electrical loads by 35 gigawatts. Seasonal thermal storage technologies now being developed promise to substantially reduce annual energy consumption (as much as 7%) through the use of winter chill, solar energy, and waste heat. Industrial thermal energy storage technologies that enable waste heat to be captured and reused within an industry will reduce primary energy consumed by industry, and therefore lower production costs. In 1989 under DOE sponsorship, the ASME assembled a panel of industrial and academic experts to review the DOE program in thermal energy storage. In general, we found the program very worthwhile and recommended that the annual budget for the program be increased to $5 million. We are disturbed that this budget proposal provides only $800,000 for this program in FY 1992, a drastic reduction from the $3 million appropriated for FY 91 and far below the ASME-recommended budget levels.

Nuclear Energy Programs

The nation needs a balanced program that addresses the near- and long-term advanced applications of nuclear energy. Thus, although we endorse the significant increase in support proposed for light water reactor certification and engineering development, we are concerned that the proposed decrease for advanced reactor research and development will preclude our ability to realize the full potential of nuclear energy in the intermediate to long-term. At a minimum, we suggest that funding be maintained at the current level.

Acceptable means for disposing of radioactive waste from nuclear power plants must accompany further development of nuclear power. Pending satisfactory resolution of waste repository issues, we

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would argue for continuation and strengthening of support for research on actinide (i.e., the heavy, long-lived radioactive waste products) burning technologies and methods. It is our view that the scope of the actinide recycle program needs to be broadened to include development of an integral reactor system that combines actinide recycle and advanced separation technologies to successfully manage actinide and other long-lived fission products. Such research is required in order to provide acceptable nuclear energy generating systems that incorporate waste minimization. We would suggest that a spectrum of advanced liquid metal reactor, light water reactor, and accelerator concepts, combined with advanced separation technologies, should be evaluated within the Department's nuclear energy research program.

Although not specifically a part of the proposed national energy strategy, the development of nuclear power systems for space applications is a significant component of the DOE nuclear energy budget request. We believe that this program is essential to maintaining the U.S. preeminence in space. To this end, we are concerned that the proposed restructuring of the space reactor power system test program would lead to a loss of momentum that would impede engineering progress. Recovery from this reduction in effort would be difficult, especially if the ground testing program is terminated.

Environmental Restoration/Waste Management R&D

New technologies and advanced engineering methods will be required to meet the challenges of remediating the environmental and hazardous waste management problems that have accumulated at our national laboratories over the decades. It is our view that the expertise residing within our government, industry, and academic institutions must be fully brought to bear on these problems. Engineering research initiatives designed to reduce both the overall cost of the program and the time necessary to accomplish the mission must be supported with this program. We are concerned that administrative and political impediments are precluding the expeditious formation of the partnerships needed to carry out a long-range collaborative engineering research program among the national laboratories, industry, and academia.

A potential measure of success of the collaborative effort would be the magnitude of the financial and technical involvement of American industry. Indeed, industry has agreed to participate in the financing of such an effort.

Engineering Research

Another area of concern to the engineering community is the potential deterioration of U.S. engineering research capabilities over the next few years. Although the NSF is generally viewed as the principal federal agency supporting such research, we believe

that the DOE's engineering research support programs that focus on key energy technology developments in robotics, fluid mechanics, multiphase flow, solid mechanics, heat transfer, automated welding, plasma processing of materials, and a host of other disciplines, are too often overlooked in these budget deliberations. For example, the budget request for the Engineering Research Program within the Basic Energy Sciences request is less than three percent of the total. We believe this situation is far out of balance. In our view there should be a commitment to double the current funding level (about $16 million) for engineering research by FY 1994. Even at this enhanced level, the needs for fundamental engineering research will far surpass the available funding.

An example of the lack of resources for engineering research has been recently highlighted by the national Academy of Sciences and National Research Council for the field of nuclear engineering. In the report entitled, "U.S. Nuclear Engineering Education: Status and Prospects" (1990), the Research Council found that federal support for academic research falls significantly short of the level necessary to maintain viability of university programs. In addition, this lack of federal support has contributed to the looming shortage of qualified engineers in this technical area, a shortage largely driven by the needs of the federal agencies and laboratories. We call this to your attention because this problem is endemic within mechanical engineering and the engineering field as a whole.

Madame Chairman and members of the Subcommittee, this concludes our statement. Thank you very much for providing the ASME this opportunity.

This statement represents the considered judgement of the Task Force of the InterCouncil Committee on Federal R&D, a group of experts in the field, rather than an official position of ASME.

APPENDIX III

Department of Energy
Washington, DC 20585
April 12, 1991

The Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy
Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Madam Chairman:

On March 19, 1991, Dr. James F. Decker, Acting Director, Office of Energy Research, accompanied by Dr. Louis C. Iannielio, Deputy Associate Director, Office of Basic Energy Sciences, testified before your subcommittee on FY92 budget request for the Department of Energy's Basic Energy Sciences, Energy Research Analyses, University and Science Education, Multiprogram Energy Laboratories-Facilities Support Programs.

Following the hearing, you submitted seven written questions to supplement the record. Enclosed are the answers to those questions.

If we can be of further assistance to you or your staff, please contact our Congressional Hearing Coordinator, Barbara Campbell, on (202) 586-8238.

Sincerely,

Jacqueline Knox Brown
Assistant Secretary
Congressional and Intergovernmental
Affairs

Enclosures

QUESTIONS FROM REPRESENTATIVE LLOYD

Question #1: During your testimony there was discussion about the ability of historically black colleges and universities to compete for DOE grants funded under the Basic Energy Sciences program. You mentioned that there are individuals on your staff that serve as points of contact who could provide assistance to historically black colleges and universities interested in applying for such grants. Would you please supply the names of these individuals and their areas of expertise?

Answer: The senior staff member in the Office of Energy Research responsible for oversight of programs with Historically Black Colleges and Universities (HBCUs) is Richard Stephens, Associate Director for University and Science Education. Mr. Stephens is responsible for DOE-university relationships as well as the management of a number of precollege and university-level science education programs. Staff contacts in the various Energy Research program offices for HBCU relationships are as follows:

Dr. Tom Kitchens, Scientific Computing and Computational Sciences

Dr. Robert Gottschall, Materials Sciences

Dr. Joseph Martinez, Chemical Sciences

Dr. Oscar Manley, Engineering Sciences

Dr. William Luth, Geosciences

Dr. Robert Rabson, Energy Biosciences

Mr. David Goodwin, High Energy and Nuclear Physics

Dr. Donald Priester, Fusion Energy

Dr. Murray Schulman, Biological and Environmental Research

Ms. Joyce Lewis, Superconducting Super Collider

Question #2: Related to the same subject, are there historically black colleges and universities that are receiving or have received significant grants from DOE for research in Basic Energy Sciences? If so, would you please supply the names of these institutions, the field of research, the amount of such grants, and the time period for which they were in effect? If not, would you specify the efforts you have underway to reach out to these institutions?

Answer: Yes we do have significant grants at historically black colleges and universities. A listing of the funding and the recipients follows:

Institution	Field of Research	Total Amount of Funds Received	Period of Funding a/
Clark-Atlanta University	Chemical Sciences	$445,835	1984-Present
Clark-Atlanta University b/	Materials Sciences	$872,490	1984-Present
Hampton University	Chemical Sciences	$289,460	1986-Present
Jackson State University	Chemical Sciences	$146,770	1988-Present
Meharry Medical College	Energy Biosciences	$390,292	1985-Present
North Carolina A&T State University	Materials Sciences	$209,000	1988-Present
Virginia State University	Materials Sciences	$242,950	1988-Present

a/ Funding for FY 1991 and beyond is dependent upon receipt, review and approval of proposals.

b/ Two individual grants; one beginning in 1984 and one beginning in 1987.

Question #3: Would you please list the 10 largest university recipients of grants in FY 1991 in each of the major BES subprogram areas (e.g., materials science, applied mathematics, biosciences, etc.). In addition, please indicate the length of time over which each of these institutions have received grants of this nature?

Answer: A listing, by subprogram, of the 10 universities that received the most funding in FY 1990 follows:

University	Length of Time a/	FY 1982-Present Funding ($000)
Materials Sciences		
Cornell University	at least 9 years	$ 11,492
Illinois, University of	at least 9 years	$ 43,206
Massachusetts Institute of Technology	at least 9 years	$ 17,995
Michigan, University of	at least 9 years	$ 4,853
Minnesota, University of	at least 9 years	$ 8,439
North Carolina State University	at least 9 years	$ 5,032
Northwestern University	at least 9 years	$ 8,113
Ohio State University	at least 9 years	$ 3,949
Purdue State University	at least 9 years	$ 12,703
Stanford University	at least 9 years	$ 18,804
Chemical Sciences		
Colorado, University of	at least 9 years	$ 5,021
Cornell University	at least 9 years	$ 4,996
Kansas State University	at least 9 years	$ 11,499
Massachusetts Institute of Technology	at least 9 years	$ 6,199
Northwestern University	at least 9 years	$ 3,682

University	Length of Time a/	FY 1982-Present Funding ($000)
Notre Dame, University of	at least 9 years	$ 29,265
Pennsylvania State University	at least 9 years	$ 5,025
Stanford University	at least 9 years	$ 76,152
Wisconsin, University of	at least 9 years	$ 3,183
Yale University	at least 9 years	$ 4,119
Engineering and Geosciences		
California, University of, Berkeley	at least 9 years	$ 4,062
California, University of, Los Angeles	at least 9 years	$ 2,105
California, University of, San Diego	at least 9 years	$ 1,987
California Institute of Technology	at least 9 years	$ 2,284
Columbia University	at least 9 years	$ 4,310
Houston, University of	5 years	$ 1,202
Maryland, University of	at least 9 years	$ 1,795
Massachusetts Institute of Technology	at least 9 years	$ 13,513
Minnesota, University of	at least 9 years	$ 2,620
Stanford University	at least 9 years	$ 9,979
Advanced Energy Projects		
Arizona University	3 years	$ 1,549
Brigham Young University	6 years	$ 1,007
Colorado, University of	2 years	$ 638
Massachusetts Institute of Technology	at least 9 years	$ 3,534
Michigan, University of	4 years	$ 615
Stanford University	at least 9 years	$ 3,104

University	Length of Time a/	FY 1982-Present Funding ($000)
Texas, University of	1 year	$ 1,130
VPI and State University	1 year	$ 115
Energy Biosciences		
Arizona State University	7 years	$ 3,142
California, University of Berkeley	at least 9 years	$ 2,982
California, University of Los Angeles	at least 9 years	$ 1,850
Cornell University	at least 9 years	$ 4,032
Georgia, University of	at least 9 years	$ 14,568
Illinois, University of	at least 9 years	$ 5,589
Michigan State University	at least 9 years	$ 22,189
Minnesota, University of	at least 9 years	$ 2,420
Wisconsin, University of	at least 9 years	$ 5,489
Yale University	6 years	$ 1,929
Applied Mathematical Sciences		
Arizona, State University	4 years	$ 1,330
California Institute of Technology	at least 9 years	$ 11,008
Harvard University	3 years	$ 977
Illinois, University of	at least 9 years	$ 17,295
Maryland, University of	at least 9 years	$ 1,751
Massachusetts, University of	5 years	$ 1,973
State University of New York at Stony Brook	1 year	$ 758
New York University	at least 9 years	$ 20,104

University	Length of Time a/	FY 1982-Present Funding ($000)
Washington, University of	at least 9 years	$ 2,448
Yale University	at least 9 years	$ 1,240

a/ FY 1982 to present data is readily available in an automated database. Data prior to FY 1982 would require manual retrieval from numerous records which would be very time consuming. We can attempt to retrieve this earlier data if necessary to meet the Committee's needs.

Question #4: What is the practice of European facilities regarding user fees for their major facilities?

Answer: European facilities do not charge user fees for their major facilities. Their practice is similar to current practice for the Department of Energy facilities in that users are not charged for research that is published and nonproprietary. The charges for proprietary research are similar to the charges at the Department of Energy facilities. The policy of the Institute Laue Langevin, the largest European research reactor, states: "Neutron beams and instrument facilities are provided free of charge for proposers of accepted experiments."

Question: Do they as a matter of policy charge U.S. scientists from the National Labs, Non-profit Institutions or the Academic community?

Answer: The European facilities do not as a matter of policy charge U.S. scientists from the National Laboratories, non-profit institutions, or the academic community; nor do they charge U.S. industry for non-proprietary research. During the time that the High Flux Isotope Reactor at Oak Ridge and the High Flux Beam Reactor at Brookhaven were shut down, many U.S. researchers, including researchers from U.S. industry, were accommodated at European facilities at no charge. Many U.S. researchers make use of European facilities which have instruments that are not available in the U.S. In turn, many European researchers use U.S. facilities for the same reason. In recent years, the number of U.S. researchers using European facilities has been greater than the number of European researchers using U.S. facilities.

Question #5: Please provide the costs expended on the Advanced Neutron Source to date?

Answer: Through FY 1991 we expect to have spent $40.8 million. The FY 1992 request is $24.6 million. All of these funds are for research and development related to the Advanced Neutron Source.

Question #6: Why does the Department propose to move the Nuclear Engineering Education and University Research Reactor programs to the Office of Nuclear Energy? Do you think these programs will enjoy support there?

Answer: No decision has been made on the proper organizational location for the Nuclear Engineering and University Research Reactor Programs. Discussions will be held with the Assistant Secretary for Nuclear Energy, Mr. William Young, regarding this issue as part of our internal deliberations on the preparation of the FY 1993 budget. A recommendation will be made to the Secretary at the proper time regarding the organizational location of these programs.

Questions #7: I know that the Department has identified women and minorities as groups that need to be drawn into fields such as Nuclear Engineering. What kind of activities has DOE initiated to address this issue?

Answer: The Department has a number of science education programs underway that provide opportunities for women and minority students to learn about careers in energy-related science and engineering. In our University and Science Education Program, support is provided through the Prefreshmen Enrichment Program for 40 summer institutes held on university campuses for women and minority middle school students. The purpose of these institutes is to provide targeted students with their first experiences in the world of science and to counsel and mentor them on possible careers in science and engineering. Our University Reactor Sharing Program includes support for research experiences for secondary school students, including women and minority students, in nuclear science and engineering. Several of our project directors report that a significant number of these students enroll in nuclear engineering or related fields when they enter college. All of the precollege laboratory rural/urban school partnerships that have been established to date include providing assistance and counselling to students on career opportunities in all energy fields including nuclear science and technology. Over two-thirds of the students involved in these partnership programs with our laboratories are minorities including Black, Hispanic and Native Americans.

TRTR NATIONAL ORGANIZATION OF TEST, RESEARCH, AND TRAINING REACTORS

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April 8, 1991

The Honorable Marilyn Lloyd, Chairwoman
Subcommittee on Energy Research and Development
2266 Rayburn House Office Building
Washington, DC 20515

Dear Madam Chairman:

Your March 26, 1991 letter requested responses to six specific questions related to my March 19, 1991 testimony on Federal Support for University Research Reactors. Please find my responses attached.

Should you have further questions or request additional information, our group stands ready to respond to you and your staff or to present additional information.

Sincerely yours,

MHVoth

Marcus H. Voth
Director and Associate Professor
Nuclear Engineering

MHV/ldl

Enclosure

Attachment to April 8, 1991 letter from Marcus H. Voth to Marilyn Lloyd

"Responses to March 26, 1991 questions from Congresswoman Marilyn Lloyd, Chairman of Subcommittee on Energy."

Question 1

For the record could you provide some data to support your comment that the U.S. research reactor program is falling behind some third world countries?

In the 1950's through the 1960's and into the 1970's the US university/research reactors (URRs) represented a capability which was superior to that of low and medium flux research reactors (comparable class reactors) in the rest of the world. However, in the period of 1970-1990 large amounts of resources were spent for neutron source development in Europe, Asia, and in developing countries. A significant fraction of these foreign expenditures for neutron sources were for medium and low flux reactors, that is, reactors of a similar class and flux level to those of the US URRs.

Examples of foreign low and medium flux research reactors constructed in the 1970-1990 time frame in countries not otherwise technologically competitive with the United States include:

Indonesia - 30 MW research and test reactor located at BATAN near Jakarata, technology supplied by W. Germany, total contract cost of $120 million US includes the building, presently under construction.

Romania - 14 MW steady state TRIGA and 300 kW steady state TRIGA capable of pulsing to 15,000 MW, provided by Gulf General Atomic at a cost of about $10 million US, without the building.

Peru - 10 MW general purpose reactor provided by Argentina, German fuel fabrication, cost of $40-$50 Million US includes lab and reactor building.

Philippines - 3 MW upgrade TRIGA provided by Gulf General Atomic, cost $3-$4 million US, startup three years ago.

Bangladesh - 3 MW TRIGA from Gulf General Atomic, $5 million US without the building.

Peoples Republic of China - 17.5 MW D_2O reactor near Beijing. A recent upgrade, cost estimate unavailable.

Taiwan - 1 MW GE reactor upgraded to use TRIGA fuel and operate to 3 MW.

Algeria - 1 MW research reactor provided by Argentina.

Morocco - 1.5 MW TRIGA provided by Gulf General Atomic, $5.5 million US without the building.

India - 100 MW Dhruva research and test reactor at BARC, operation started 1988, cost likely to be in the $100+ million US range.

The reactor projects listed above have been carried out in the last two decades in countries which can be characterized as developing or underdeveloped. Furthermore, these reactor projects deal with low and medium flux reactors which in many ways can be considered in the same class as US URRs. By contrast to the many foreign projects in underdeveloped or less developed countries, there has not been any federally funded major upgrade or new URR in the United States during the same time period.

Note: The five remaining questions were asked of both Dr. Marcus Voth who represented URR facilities (TRTR-National Organization of Test, Research, and Training Reactors) and Dr. Barclay Jones who represented nuclear engineering education programs (NEDHO - the Nuclear Engineering Department Heads Organization). These questions will therefore be answered only from the TRTR perspective, addressing URR facility issues.

Question 2

Could you discuss for us how the colleges and universities responded to the NAS/NRC reports on nuclear engineering education and university research reactors?

The NAS/NRC study found that "...on-campus research reactors contribute to academic values through research and education at the university, and through service to off-campus user constituencies." Numerous examples are cited. Universities have continued to subsidize URR operations heavily to continue these valuable contributions, despite the lack of outside support. Our group recently studied URR funding sources and found host institutions covering 85 percent of the cost of reactor operations.

The University Reactor Instrumentation Program was initiated with $1 million of federal support in FY 90 and continued with another $1 million in FY 91. This program has been tremendously successful. Numerous critical equipment needs have been served at a modest expense. Universities responded by contributing the engineering, design, and installation labor not covered by the program and in most cases provided other matching funds.

Question 3

Are any of the recommendations from the National Academy Report being implemented?

Yes. Some of the recommendations are being implemented but not all and far below the recommended level. For example, the federal funding discussed in question 2 has been at $1 million per year whereas the report recommends $20 million per year. The report states, "Needs include modern instrumentation, low temperature irradiation facilities, cold neutron capabilities, modern spectrometers, radiographic equipment, increase power and neutron flux, and other enhancements." The need for modern instrumentation is being addressed at a low level. There has not been funding

available to consider the larger needs such as increased power and flux or cold neutron sources.

The report calls for "...a reactor network to provide enhanced utilization and productivity of US research reactors..." Since the report was written, the capabilities of all URRs have been listed on the FEDIX system to direct researchers to the facility that will best serve their needs. TRTR has become more active and initiated a newsletter which strengthens the established network of members representing university, commercial, national laboratory, and military non-power reactors.

The report calls for the NRC to "...examine its current approach to licensing and regulation of university research reactors..." The NRC has taken numerous steps to better understand the unique nature of non-power reactors. Effective dialog has been established between TRTR and the NRC from the staff to commissioner level. Through a restructuring within the NRC, non-power reactor matters are focused in a single group which understands non-power reactors.

While such action is being taken to implement certain of the National Academy recommendations, one cannot escape the central message that significant federal support is needed. Without the funding there cannot be significant implementation of the recommendations. The executive summary calls for a strategy requiring the following:

> "In pursuit of this strategy the Federal government should:
>
> - adopt the goals of meeting US research reactor needs, and regaining a position competitive with Europe and Japan in the neutron-based sciences;
> - study, in detail, the approaches of other advanced countries to operating research reactor networks such as that of linking the major facility at Grenoble with smaller reactor research centers in Europe (see Chapter 5);
> - establish and support such a network, adapted to US needs;
> - make up to $20 million available annually (as a preliminary estimate to be modified as improved data becomes available) to universities through the designated federal agency, specifically for operational support and facility upgrades of university research and educational reactors (see Chapter 7); and,
> - create a peer review mechanism to assist the designated agency in making grants to universities."

If perspective is maintained, one will observe that the root of the Academy recommendation is significantly increased federal support and that has not been implemented beyond the 5 percent level.

Question 4

Could you address the numbers of students entering this field at both the undergraduate and graduate levels? And, could you discuss the employment issues, such as where these graduates actually work?

This question refers to nuclear engineering education and can therefore be best answered by Dr. Jones of NEDHO. It must be noted, however, that reactor users comprise a much larger spectrum of disciplines than nuclear engineering.

Question 5

From your perspective, what do you see as the role for DOE or the federal government in these areas -- aside from funding?

There are two primary non-fiscal areas where DOE or the federal government can be of assistance. The first is in formulating a national energy policy. Even as this response is being prepared the University of Maryland has commissioned a high level study to consider the viability of their nuclear engineering program and reactor operation. One reason cited was the amount of time that the nuclear option has been dormant and the lack of a definitive endpoint to the dormancy. A clear national energy policy supported with decisive action in such areas as one step licensing of nuclear power plants and high level waste disposal would answer questions of numerous university administrators.

A second and more global issue considering the full spectrum of reactor users is leveling the playing field for the limited resources available. Data shows significant accomplishments in education and research with limited resources ($30 million for all URRs) relative to other research expenditures. The national interest is best served by investing its research funds where the return is highest. While the Academy study calls for increased funding for URRs on an absolute scale, we believe a high standard peer review of all related research funding will show that the existing federal expenditures can be implemented more effectively by directing a larger share to URRs.

Question 6

Recent reports have indicated that not only are students not entering nuclear engineering and related fields, but there is also a problem of losing our teaching capabilities. Would you comment please?

This is primarily a NEDHO question. However, quality research facilities are critical to attracting and retaining top faculty. If URR's age with little or no upgrade or modernization, as has been the case in the United States, top caliber experimenters will no longer be attracted into the profession.

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May 7, 1991

Ms. Marilyn Lloyd, Chairman
Subcommittee on Energy
Committee on Science, Space and Technology
Suite 2320 Rayburn HOB
Washington, DC 20515

Dear Ms. Lloyd:

Thank you for the opportunity to respond to the several questions which were posed to me following my testimony on the DOE FY92 budget request for Basic Energy Sciences on March 19, 1991. My response is attached and has been sent separately by fax to Ms. Cheryl Faunce.

Unfortunately it took somewhat longer than anticipated to clarify the present status of ongoing activities in Government, Industry and University related to your questions. I trust that my responses will provide you and your staff the needed information to proceed with budget items related to Nuclear Engineering and University Research Reactors. If further information or clarification is needed, I will be pleased to respond.

Sincerely,

Barclay G. Jones
Professor and Head
and Past Chair of NEDHO

BGJ/kmd

CC: NEDHO Exec. Comm.

Responses to Questions by Barclay G. Jones
Relating to Testimony on DOE FY92 Budget Request
for Basic Energy Sciences

1. Could you discuss for us how the colleges and universities responded to the NAS/NRC reports on nuclear engineering education and university research reactors?

The nuclear engineering education community has responded to the NAS/NRC reports on nuclear engineering education and university research reactors in several ways and is continuing to respond with new thrusts. We view both reports as being strongly supportive of nuclear engineering, and we believe that their detailed examination of the fundamental aspects of both education and university reactor issues, with the natural interdependence of both communities, provides an important base from which to rebuild and to strengthen them.

First and foremost, the University programs have focussed on disseminating the information in both reports. Specifically the Nuclear Engineering Department Heads Organization (NEDHO) has utilized special sessions at technical meetings (e.g. ANS semi-annual national meetings, Nashville, June 1990; Washington DC, November 1990; a scheduled round table at Orlando, June 1991; and a review of the communities response at San Francisco, November 1991) to highlight the reports and their recommendations. Within the University the departments and programs have communicated the materials to their administrations, which in many cases provides the much needed information to enable the educational units to be sustained within the currently strained higher education systems.

Regionally, departments and programs have communicated the findings to the full spectrum of nuclear industries, particularly to the nuclear utility companies, and where applicable to the national laboratories. In each of these areas, the identified lack of newly graduating nuclear engineers is being met with concern.

At the national level, NEDHO has continued to appraise members of congress and their administration staffs of the findings and recommendations. In particular, beyond your staff and sub-committee members, meetings were held with both Representative Bevill's staff (Mr. A. Edmundson) and Senator Johnston's staff (Mr. P. Jones). Additionally, meetings with staff at the Office of Management and Budget and the Office of Science and Technology (Dr. Erb) have been held and the reports of both studies were transmitted and discussed.

In these various meetings we have discussed, not only the findings and recommendations, but the needs for, and the consequences of, not receiving improved financial support. We have continued to urge the adoption and support of the program which we have jointly recommended with TRTR to your Subcommittee.

2. Are any of the recommendations from the National Academy Report being implemented?

In response to the question concerning whether any recommendations from the National Academy Report are being implemented, I will respond by

indicating what I believe is the status of the recommendations in each of the three segments of the discipline as identified in the report and given in summary form in Attachment A.

In the recommendations to "Government" several of these are being pursued, but to my knowledge none have been completed at this time. The first two are part of the current FY92 budget considerations and are incomplete. However, only in the proposed budget of the Office of Nuclear Energy has there been direct support of the first recommendation, i.e. $2.5 million dollars for fellowships and scholarship programs and for improvements in university nuclear engineering departments and curricula. DOE funding of national laboratory programs in support of women and minorities appears to be occurring, but it is too early to assess the magnitude and relative impact this funding will have in the university community.

The DOE response to Congress's directive last year from the Committee on Appropriations, "to complete a plan for the utilization of all university-based research reactors ----" includes many positive aspects (Re: Secretary Watkins' letter of August 9, 1990 to Congressman Bevill), indicates active steps are being studied and developed to address university research reactors. The status of these were reported to Congress with the referenced letter. This is a positive action, but the full impact is not yet known as none of the steps is complete as far as I am aware.

The final recommendation, concerning the ORAU data base is underway, but is not yet complete. If it were available the response to your question number 3 could be made more definitively.

In the recommendations to "Industry", an initiative by Mr. O'Connor, CEO of Commonwealth Edison, to Mr. Young, Assistant Secretary for Nuclear Energy, to provide matching funds to nuclear engineering programs to address the first of the two recommendations was made early in this calendar year. Indications are that a multi-year program could begin as early as the next academic year, 1991-92. Such a program could significantly impact nuclear engineering education. The breadth, levels of funding, and the guidelines for administering the funds in the proposed program are still in the planning stage. The second recommendation, concerning continued work with the American Nuclear Society as an advocate for nuclear engineering education is being pursued and has been broadened by establishing a liaison with IEEE and ASME educational communities.

In the recommendations to "Universities", several related themes appear. One of these is to move curricula and research to encompass more strongly fission reactor areas as well as waste management and biological-environmental areas. Formally this is a slow process, but informally this is occurring via newly available graduate fellowships in waste and environmental clean-up and restoration. In addition, undergraduates make elective course selections which reflect the availability of jobs in these areas.

To effect research direction changes will require the availability of research funding, which would appear to be a chicken and egg problem. The initiative of the Savannah River Site in sponsoring four research projects last year is a good example of how such directions and emphases can be changed in a short time frame.

At the present time university administrators across the country are uniformly under stress by the weak economy, and until a recovery of the economy occurs there is little likelihood that staffing of nuclear engineering programs is likely to change and could continue to shrink. Clearly nuclear engineering education is vulnerable, and until the industry undergoes a resurgence this is unlikely to change significantly.

3. Could you address the numbers of students entering this field at both the undergraduate and graduate levels? And, could you discuss the employment issues, such as where these graduates actually work?

In response to this question of numbers of students entering the field at both the undergraduate and graduate levels, the data base is less well developed than desirable for numbers entering the university, but it is well developed for those graduating at each level (B.S., M.S. and Ph.D.). For those completing studies, the decreasing graduation trends at all levels identified in the report have continued, due in part to the loss of additional educational units. For those entering educational study, we have only anecdotal information, which suggests that the number and quality of applications to graduate study have shown perceptible increases this year. There would seem to be no clearly identifiable cause for this, but undoubtedly the recession is having some effect in current hiring practices. However, since the supply has become somewhat smaller than the demand for nuclear engineers, the selected hiring freezes are having limited impact, primarily only in the variety of job opportunities. For example, at the Savannah River Site where a planned reduction in employment level is occurring, this reduction is expected to come primarily from external contractor employees and through attrition. Job reassignments are being used to meet most immediate staffing needs while selective hiring is employed for special needs. The graduates from nuclear engineering programs have been well documented for job categories through the employment base at ORAU, but this base does not reflect the specific employers for which our graduates work. To give you a flavor of this, I have included as Attachment B a listing of the employers to which our three levels of graduates have gone over the past two years. Although this may vary somewhat by region and by school, I believe our experience is typical.

4. From your perspective, what do you see as the role for DOE or the federal government in these areas - aside from funding?

From my perspective, I see the role of DOE, aside from funding, as one of cooperation and shared leadership in assuring that the country's manpower needs are met for a well educated supply of nuclear engineers at all degree levels. Clearly no one segment by itself can meet these needs, not universities, not industry and not government. It is important that each recognize their contribution to the education process, including that of funding. Further, I believe that each segment needs to recognize the unique role which nuclear engineers can and should contribute to each of the three segments. Certainly the recent anniversary of Chernobyl reminds us of the need for nuclear engineers in both design and operation of nuclear power plants.

DOE, acting cooperatively with nuclear engineering programs can provide unique facilities for graduate research and can identify challenging research and development projects on which students can contribute, either on an individual basis on a separate research topic or in conjunction with mission oriented programs. I firmly believe that universities can significantly contribute to mission oriented research, and advisors and their students need opportunities on which to demonstrate this.

5. Recent reports have indicated that not only are students not entering nuclear engineering & related fields, but there is also a problem of losing our teaching capabilities. Would you comment please?

I am not specifically aware of the rational which the reports, to which you refer, use in concluding that students are not entering nuclear engineering and related fields. It is true overall that fewer students are entering the field, but in part this is due to a reduction in the total number of nuclear engineering educational programs. Thus, geographics play a role, particularly at the B.S. level. However, I believe the statistics of the undergraduate enrollments at most major programs has stabilized and has improved slightly over the past year or two. Clearly the current dip in population in the 18 to 22 years age group could be contributing to any observed reductions. Although the information is anecdotal, graduate applications at many nuclear engineering departments this spring appear to have improved in both quality and quantity. It is too early to know if this is a bonafide trend, but enrollment statistics in the Fall 1991 should clarify whether this trend occurred.

I think there is little doubt that the nuclear engineering discipline is losing some of its teaching capability. This is especially true due to the closing of units and to the absorption of units into other discipline departments, which typically reduces the capability of these programs. In the current state of a weak economy, higher education in general is down-sizing, which makes small units particularly vulnerable and nuclear engineering is no exception. With an aging faculty, nuclear engineering is even more vulnerable to loss of capability, particularly in the power reactor area.

Attachment A

STATUS AND PROSPECTS OF U.S.
NUCLEAR ENGINEERING EDUCATION
by
NATIONAL RESEARCH COUNCIL, JUNE 1990

Recommendations

- *Government*
  - *Funding for trainee and fellowship programs should be increased.*
  - *A $7 million annual increase in funding for power-reactor-related research is recommended.*
  - *Programs to attract women and minorities should be enhanced.*
  - *DOE should assess the feasibility of supporting access to a network of research reactors.*
  - *DOE should upgrade its personnel data base in nuclear engineering.*
- *Industry*
  - *Electric utilities and the supporting industry should increase their support of cooperative student programs, research scholarships and fellowships, seminars, and academic chairs.*
  - *Industry should continue working with the ANS in providing strong advocacy of nuclear engineering education.*
- *Universities*
  - *Undergraduate curricula should increase emphasis on systems-oriented reactor engineering, biological effects of radiation, and oral and written communication skills.*
  - *At both undergraduate and graduate levels, more emphasis should be given to nuclear waste management and environmental remediation.*
  - *Research programs should include significant effort in reactor-oriented areas.*
  - *Faculty should seek support for research related to power reactors, nuclear waste management, and environmental remediation.*
  - *University administrators should consider innovative approaches for the timely addition of junior faculty.*

DEPARTMENT OF NUCLEAR ENGINEERING STUDENT EMPLOYMENT

1988 - 1989

B.S.

Student	Employment
Curt Abegg	Grad School/ U of I
Regina Marie Demers	Wordlink Co., Champaign, IL
Michael O. Cornell	Grad School/ U of I
Roger Hamilton	
Michael J. Hutcheson	
Randall H. Jacobs	Commonwealth Edison
Michael R. James	Grad School/U of I
Brian Edward Jelke	Grad School/U of I
William Louis Jorns	
John Francis Kotek	Department of Energy
Daniel Jude McLain	U.S. Navy
Patrick R. Murphy	Grad School/North Carolina State
Jon Warren Neuhoff	Grad School/U of I
Brian Wayne Sampson	Commonwealth Edison
Nirodh Shah	
Kenneth E. ter Horst	
Ronald Frank Weber	Grad School/U of I

M.S.

Robert Yi Zhen Bai	Grad School/U of CA-Berkeley
Ravi C. Venkatesan	Grad School/U of I
Mohammad M. Islam Raja	Grad School/Stanford Univ.
Robert Peach	General Electric
Brian Mark Golchert	Grad School/U of I
George M. Hrbek	Grad School/U of I
Jason Eugene Huffer	Allied Chemical
Glenn T. Sager	Grad School/U of I
Jeffrey P. Schneider	Grad School/U of I
Tyrone Stevens	Commonwealth Edison
Brian Boyle	California -
Musa Danjaji	Grad School/U of I
Paul Domagala	Delft Univ., Netherlands
Ronald Kucharski	U.S. Navy
Baolan Shi	Grad School/U of I
Jeffrey Wilson	Sargent & Lundy
William J. Wlaschin	Commonwealth Edison

Ph.D.

Mitchell T. Farmer	Argonne National Lab.
Hrabri L. Rajic	Kuck & Associates, Urbana
Francesco Venneri	Los Alamos National Lab
Walter San Horton	Military, Kirtland AFB, NM
Lefteris H. Tsoukalas	University of Tennessee

DEPARTMENT OF NUCLEAR ENGINEERING STUDENT EMPLOYMENT

1989 - 1990

B.S.

Student	Employment
Alice Arendt	Grad School/U of Michigan
Michael Needham	
Richard Park	Commonwealth Edison Co.
Lisa Rettke	Grad School/U of IL
Richard Wayne Brock	Grad School/U of IL
Elaine Theresa Fiolka	Westinghouse. Hanford (BNW)
Brent Timothy Heilman	Dept. of Energy, U.S. Navy
Kendall Jon Hollis	Grad School/U of Wisconsin
Scott Kenneth Kujak	Westinghouse, Pittsburgh
Daniel William Lamond	NUTECH
Craig A. Laughton	Grad School/U of IL
Daniel J. Lillyman	Illinois Power
Hyun Duk Park	Continuing Studies, U of IL
Robert B. Turkot, Jr.	Grad School/U of IL

M.S.

Don Patrick Bosnic	Niagara Power
Hans T. Weger	Grad School/U of IL
Siyuan Yang	Grad School/U of IL
Mark Vandermyde	Illinois Power
Jonathon H. Nadler	Grad School/U of IL
Edward B. Seal	U. S. Navy
Dandong Wang	Grad School/U of IL
Andreas Ikonomopoulos	Grad School/U of Tennessee
Laura Nanko	Grad School/U of IL
Jon Warren Neuhoff	Commonwealth Edison
Phi Long Nguyen	INTEL, Beaverton, OR
William Leon Myers	Grad School/U of IL
S. Raghuraman	Grad School/U of IL
Wade Henry Williams	Grad School/U of IL

Ph.D.

Bruce L. Cain	Mississippi State University
John B. O. Caughman, II	IBM, New York
Kai-Youarn Hour	Mechanical Engr. Dept.
Keeman Kim	Argonne National Lab.
Abdel-Latif M. Yacout	Argonne National Lab.

Questions for the Record
Dr. David E. Moncton
Associate Laboratory Director
Advanced Photon Source
Argonne National Laboratory

1. You mentioned that some foreign research projects would be conducted at the Advanced Photon Source. Do U.S. researchers receive the same courtesy at overseas research facilities?

   In all European and Japanese facilities, U.S. researchers are welcome on the same basis as local scientists.

2. Are there any limitations proposed for foreign users of APS in terms of numbers of experiments, users, or percentages of time? Do U.S. researchers experience any such limitations?

   Due to the quality and accessibility of foreign facilities we expect few requests for beam time. As a matter of policy, we do not plan to discriminate against foreign users. This policy could be reconsidered if foreign dominance became an issue, which is very unlikely.

3. To the best of your knowledge do U.S. (non-proprietary) users of foreign user facilities pay significant user fees? If so, do you know how much is charged?

   No. In fact I believe there are cases where foreign facilities have paid for the travel of experimenters from the U.S.